APPLYING SEARCH THEORY AND COORDINATED INCIDENT MANAGEMENT TO AVALANCHE RESCUE

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ABSTRACT: Search theory was developed by the USA during World War 2 Koopman (1946, 1980) to make hunting for submarines more effective. Its key concepts of: Effective Search Width, Effort, Probability of Area, Probability of Success and Probability Density are applicable to avalanche rescue. By combining the search theory concepts with likely burial survival times it is possible to forecast the likely probability of a live find in an area in the debris, if a particular technique is applied at a point in time with a certain level of resources. The coordinated incident management system (CIMS) is the incident management system that has been adopted in New Zealand. Utilising the search theory concepts and the principles of CIMS at large scale avalanche rescue responses should lead to an increased likelihood of live finds.

1. INTRODUCTION

Search theory was developed during World War 2 by the United States Navy for finding enemy submarines. Koopman (1946, 1980) Use of search theory made the searching resources more effective at their search tasks. Search theory contains a number of key concepts, all of which are applicable to avalanche rescue. By incorporating probable avalanche victim survival times it is possible to forecast the probability of a live find for different techniques. CIMS is a standardised way of managing incidents. At its core are seven principles. Applying these principles should improve effectiveness and aid the application of the search theory concepts. As the underlying goal of avalanche rescue should be maximising live finds all search actions taken should be trying to achieve that goal.

2. KEY SEARCH THEORY CONCEPTS

2.1 POA – Probability of Area

This is how likely is it that the search object is in the place being searched. POA is best arrived at by consensus between a number of knowledgeable experts. It is done by splitting the debris to be searched into a number of areas that are likely to have a similar level of probability through out them. They then have a percentage likelihood assigned. The most important feature of these areas is that the likelihoods assigned must be proportional.

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Figure 1: An example of a rescue site that has been split into areas by probability then segmented for searching.

In the example in figure 1 the debris is split into three areas and assigned proportional likelihoods based on the information available. A is 9 times more likely than B and 3 times more likely than C. C is 3 times more likely than B. This then produces the POA. Pden is derived by dividing POA by area. The importance of the Pden is its comparative size. In the example above this means that the chances of finding the search object in C is 1.33 times more likely per m² than in A even though its POA is only a third of A.

If the areas are then segmented into searchable segments POA is split across them in proportion to their size. POA of a segment equals its Pden times its area in m².

2.3 ESW – Effective Sweep Width

This is the measure of the detection potential for a resource. It is the width that a search system (probe, transceiver, etc) is effective to for finding the search objects in its search path. ESW is not the maximum range of the search resource. It can be made up of a variety of ranges of effectiveness. For instance a transceiver might be able to find everything within a 20 m sweep width and 75% of things between 20 m and 30 m sweep widths and 25 % of things between 30 m and 40 m sweep width and nothing beyond a 40 m sweep width. Its ESW would be 30 m as that is the range where it finds as many things beyond that range as it misses inside it. Quincy Robe, Frost (2002)

2.6 Effort

This is the speed times the time a resource is searching.

2.4 POD – Probability of Detection

This is how effective is the search technique? It is made up of a combination of effective sweep width and effort. POD = ESW x effort.

2.5 POS – Probability of Success

This is how likely is the search object to be found? POS = POA x POD. POS is cumulative. As successive searches are done of a segment more and more POS is extracted from the POA of that segment.

3. AVALANCHE SPECIFIC CONCEPTS

There are two further concepts that are in addition to the standard search theory concepts.

3.1 POL – Probability of life

POL is the probability that someone is still alive after a period of time buried. New Zealand has adopted a generic burial survival model for use in rescue planning. As there is no comprehensive New Zealand data on burial survival times a mixture of the European and Canadian survival curves Haegli, Falk, Brugger, Etter, Boyd (2011) has been used to give search managers guidance on possible survival times and the four key phases of a burial.

Figure 2: The POL chart, distributed by NZSAR. This is used for avalanche rescue planning in New Zealand. The stripped blue lines indicate that the change from the latent 3rd period to the final period occurs somewhere in that time zone.

While it is possible that the chart in figure 2 indicates higher survival times than may exist in New Zealands maritime climate it does give incident controllers, rescuers and search planners some context for their actions. It emphasises the behaviours needed to get the best possible outcome; the need for urgent action by those on site during the first two periods, the potential for external rescuers to make a difference if they can get on site fast enough and the need to continue till the last victim is found.

POL needs working out by taking the time since the avalanche plus the search time for the place of interest plus the likely digging time. This gives the total probable burial time that can be used to give the POL estimate either by using the graph or a
table with the POL times in it or a search calculation app.

3.2 POLF – Probability of Live Find

This is how likely is a live find if a particular technique with a defined amount of effort is used starting from a particular point in time.

\[ \text{POS} \times \text{POL} = \text{POLF} \]

4. GUIDENCE NOT ABSOLUTE

It must be emphasised that the POL and therefore POLF are guidance concepts for search planning. Individual survival times in an actual event will vary with the circumstances, particularly with things like the likelihood of trauma and the snow density. The following examples show the likely influence of snow density.

Figure 3: Blocky debris with air gaps. Photo taken 1 hour after the avalanche occurred.

This debris in figure 3 from a size 2 avalanche on Mt Ruapehu has a large number of interconnected small air pockets. No one was buried in this avalanche but if someone had of been it would seem highly likely that they would have survived for a long time. Mt Ruapehu is well known for its maritime snowpack and dense snow. The assumption would have been that any avalanche there would produce low survival times.

Figure 4: Debris with no air gap. The rod is a 2 m long ruler. Photo taken the day after the incident.

The debris in figure 4 is from an avalanche incident in the Ragged Range in the Southern Alps, where at the time of the event the snow that avalanched was of low density (by New Zealand standards). Despite a very fast rescue of less than 10 minutes the victim died of suffocation. The debris was very tightly packed fine grains.

Rescuer observations of the debris characteristics of the event should therefore be taken into account when predicting possible survival times.

5. COVERAGE AND POD

Koopman produced the coverage versus POD exponential model which is shown on the right hand curve on figure 5. He showed that random searching produced POD which depended on how much coverage (ESW x effort) that searching would produce. Enough random search effort to have covered the area twice produced a POD of around 85%.

Figure 5: Comparison of random and systematic coverage.
The line to the left on figure 5 is what can be achieved through systematic parallel sweeps that does not leave any gaps or do any overlaps. The reality for searchers is that producing 100% coverage with no gaps or overlaps is not possible when searching on avalanche debris. This means that some places will get searched more than once which will increase the time it takes to get 100% coverage or places will get missed which will lower the coverage amount if searchers think they have done enough effort for 100% coverage. The implication for searchers is that efforts to avoid gaps in searching can slow the resource down and most likely produce overlaps which can be wasted effort.

The effect of this is shown in figure 6. The four curves represent a single transceiver searcher searching 4 ha, 2 ha, 1 ha and 0.5 ha of debris with sweep widths from 20 m to 60 m. If 5 minutes was allowed for digging, the searcher travelled at 3 kph, had a transceiver with an ESW of 30 m and started immediately after the event the curves show the possible POLF. Altering any of these variables will produce different curves. With the 0.5, 1 and 2 ha debris the maximum POLF is derived from using the ESW. For the 4 ha area maximum POLF is derived from increasing the sweep width which lowers POD but means that the area is searched faster. With the 0.5 and 1 ha areas if the searcher errs on the side of narrow sweeps a better POLF is achieved than erring on the wider side of the ESW. With the 2 and 4 ha areas erring on the side of larger sweep width produces a higher POLF than erring on the side of tighter sweep width.

Knowing the ESW of a resource is a critical factor. There is not a lot of good information on this available. Information is nearly entirely lacking with visual search and in the case of transceivers the information is often misleading as maximum range is what is usually promoted by manufacturers.

Being able to mark where searching has occurred is needed to be effective when dealing with larger sites.

6. PRODUCING THE GREATEST POS FOR LEAST AMOUNT OF EFFORT

There is a fixed amount of POS in each segment. Search effort needs to be directed at the places that POS can be maximised. That is the greatest POS for the least effort. POS is like the beer in a stein, when you remove some it is gone. You can only get more added if new clues indicate higher POA. When this happens other areas need their POA adjusted as well so the same overall amount remains. If you search without finding anything then the amount of POS (POA x POD) needs to be deducted from the segments POA for the next set of calculations. For example if you had two segments of equal effort to search, S1 with 80% POA and S2 with 20% POA and if the search technique had a POD of 65% then it would take two passes of the 80% segment with no results to get the POA of S1 down to below the level of S2.

POS = POA of 80% x POD of 65% = 52%. Starting POA of 80% - 52% becomes a new POA of 28%.

28% x 65% = 18% 28% - 18% = 10%

After two unsuccessful searches of S1 its POA is now 10% and S2 is 20%. As the effort to search them is equal more POS can be extracted from S2 with the next search pass than from S1 so S2 is now the best place to search.

7. APPLYING CIMS TO AVALANCHE RESCUE

New Zealand has adopted the Coordinated Incident Management System CIMS. Ministry of Civil Defence and Emergency Management. (2005).This is very closely modelled on the North American ICS. To get the maximum effectiveness from large numbers of rescuers rapidly arriving on site and to make the best use of search theory the CIMS principles need applying and a large amount of control applied to the resources.

7.1 CIMS principles

CIMS has the following principles:-

• Common terminology
• A modular organisation
• Integrated communications
• Consolidated incident action plans
• Manageable span of control
• Designated incident facilities
• Comprehensive resource management

7.2 Using CIMS

At times there is a counter intuitiveness of applying a high degree of control. It may seem that time is being used to manage things rather than do things. The reflex tasking that companion rescuers apply so effectively to their responses can produce a whole range of resource use effectiveness issues if applied to large scale incidents.

Observations at large scale avalanche rescue exercises that had rescuers arriving by multiple helicopters all within a short time frame showed that what would have been effective strategies for companion rescue produced reduced effectiveness. Control broke down, essential equipment got left in places where it was not accessible, some places got multiple searches done of them prior to other just as likely places getting searched. The multiple searching occurred through two reasons, the ASC tasking more resources to search with out the new resources knowing what had already been searched and self tasking rescuers deciding to do some searching of previously searched places. While the desire to do everything as fast as possible particularly when still inside the first 3 phases of the victim survival curve is highly desirable too much self tasking even by highly skilled practitioners is likely to lead to overall lesser results.

Applying the search theory concepts to the management of a large avalanche rescue site shows that if rescuers arrive within the first 35 minutes allowing some of the initial responders to self task using good companion rescue skills will increase the probability of live finds. This is because any effort applied within the critical high POL early periods yields relatively high POLF compared to more organised effort applied during lower POL periods later on. However as more rescuers arrive the overall effectiveness of the search will decrease unless control is established and appropriate tasks assigned. This is because there is likely to be excessive coverage of some places and gaps in others. If rescuers can get on site during the 3rd victim survival phase (latent period) it is important to attempt to search all likely places in an effective manner before the drop off into the limited survival phase. To make the best use of resources it will be important to mark where previous effort has occurred to limit wasted effort.

Avalanche Site Commanders (ASC) need to ensure that their component of the operation has the following attributes so that they can apply CIMS principles:-
• A manageable span of control, so that they can mange the resources effectively and have space to think ahead.
• Designated entry and equipment storage points, so all incoming resources can receive appropriate briefings and so important equipment is accessible.
• Rescuer taskings-briefings, so that all resources are aware of everything they need to be aware of and are given tasks that makes them effective. It also assists with recording who is on site to help mange site safety.
• Good information on incoming resources, so that decisions can be made based on what will be on site within the near future rather than just based on what is there now.
• Places searched and all items of interest marked, so that search effort can be applied effectively.

8. CONCLUSION AND KEY POINTS

In order to achieve the goal of maximising live finds there is a need to make the most effective use of the resources. The search theory concepts and CIMS principles will assist with meeting that goal. While it may not be possible to do the calculations on site during the early stages of an event the concepts should still be used to guide actions on site. Search theory can be used for good effect when planning for incident responses and when assessing the effectiveness of different strategies or when developing new techniques or looking at variables with them. Search theory including doing the calculations should be used for effective management of resources during a prolonged incident and can be a key input into decisions on whether to stop searching.

8.1 Key Points
• Applying Search Theory increases effectiveness
• Understanding search theory concepts is important for avalanche rescue
• ESW, POLF and diminishing POA as POS is extracted are key concepts
• Use search theory when pre planning and testing new techniques
• Applying CIMS principles increases effectiveness
• Need people on site who know how to manage organised rescue
• Need good information flow to ASC

While a lot of effort goes into medical equipment and expertise, transceivers, dogs and helicopters it is important to recognise that a significant contributor to the effectiveness of a major avalanche rescue site is having a large number of colour coded marker wands available on site.

9. FURTHER WORK NEEDED

To get greater value out of search theory in avalanche rescue there is a need to establish more accurate effective sweep width information for the techniques being used. This is particularly important for visual search where there is no established effective sweep width information.


