The Value of Searching by Voice in LandSAR

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Abstract

This study is concerned with off-track foot searching for a missing person who is presumed wanting to be found and who is by nature responsive.
The study explored the hypothesis that searching just by calling and listening is superior to any other on-foot methods, even though the missing person's responsiveness will decline over time.
Spreadsheet modelling has been used to calculate the comparative probabilities of success of various strategies, employing three common search methods either exclusively or in combinations.
Results strongly favour searching by calling and listening exclusively while the search objective is to save the missing person's life, that is, to ignore the possibility that the missing person is no longer responsive.

KEY WORDS: *LandSAR, missing person, search strategy, voice searching, Probability of Area*

Introduction

Off track foot searching is undertaken predominantly by sight, calling, and listening. Search methods that maximise emphasis on detection by sight are usually called Line or Grid Searching. Normally, detection by sound would be considered a windfall to such searching. Any method that seeks to optimise the use of sound, leaving detection by sight to good fortune, can be thought of as being at the other end of a spectrum of methods. Many methods have been devised that fall between.
Typically, search planners must use experience and judgement, together with medical advice to decide on the optimal search method or methods to employ. The search planners will be reviewing those decisions at every stage of the search to maximise efficiency and effectiveness. It would assist a search planner to know where on this scale lies the optimal search method, or combination of methods, at any point of time in a search operation. Further, a consideration in method selection is the search objective: either to save the missing person (MP) or to find the MP's remains. While the literature reviewed describes methods in detail, selection of methods as options in a strategy and its relationship to current search objective has received less attention.
The 2003 review of LandSAR literature for the U.S. Department of Homeland Security and the United States Coast Guard (Cooper et al, 2003) provides a concise summary of literature to that time. The authors provide some insights into strategy under the heading "Effort Allocation" but do not reference any direct empirical search method comparisons. The review is critical of preceding LandSAR studies

relating to their treatment of Probability of Detection (POD) as applied to clues as if all clues are of equal detectability. However, the review does not extend this principle to missing persons (MPs) in different physical states.

Operations manuals provide a little more direction. In *Managing the Lost Incident,* (Hill et al., 2011), the authors devoted a chapter to Allocating Resources. Prominence was given to searching by widely spaced “Sound Sweeps” using whistles. In Cooper et al, 2003, the authors broadly divided detection methods into “indirect” and “direct”. “Indirect” refers to methods of drawing the MP to safety, e.g. sounding a horn, and “direct” referring to active searching. The search methods examined in this paper, *Voice in LandSAR,* would all be classified as direct searching. Hill et al, 2011 listed direct methods as Hasty Searching, Loose Sweep Searching and Tight Sweep Searching. While not explicitly included in this list, Sound Sweep was discussed at length and corresponds closely to the description of Loose Sweep Searching. Calculations in this paper, *Voice in LandSAR,* suppose use of the method of Voice Searching described in Appendix 1. This would similarly fall into the category of Loose Sweep Searching. Tight Sweep Searching explicitly includes Grid Searching, which mathematically closely approximates the Line Searching used for comparative purposes in this paper (*Voice in LandSAR).* Hill et al, 2011, then recommended employing one of these three categories at each of three distinct phases of a search: at the start; when thoroughness is required; and/or when other methods have failed. Loose Sweep Searching was described as suitable only while the MP is likely to be responsive. However, no consideration was given to any relationship between selection of method and search objectives.

Also published in 2011, and probably the most influential LandSAR manual, is the *Addendum to the National Search and Rescue Supplement to the International Aeronautical and Marine Search and Rescue Manual V1* of the [UN] National Search and Rescue Committee (2011). In its description of search methods, the structure of the Addendum closely resembled that of Hill et al, 2011. In relation to selection of methods, the Addendum offered only that Rapid (Hasty) Searching comes first and rarely extends far from the Last Known Point (LKP). Sound Sweep was given less prominence than in Hill et al, 2011 but it noted that Sound Sweep is fast but relies on MP responsiveness. Neither was discussed in the context of search objective.

Another manual at the level of national application which is in the public domain and which applies to this author’s own region is the *National Search and Rescue Manual published by the Australian Maritime Safety Authority* (2019). This categorised LandSAR methods as “Fast/ Reconnaissance”, “General Search” and “Contact Search”. Nine patterns of “Contact Search” are described. Diagrams imply, though the text did not state, that eight, or possibly nine, of the “Contact Search” methods are primarily sight-based searching. Among them, “Parallel Sweep” and “Creeping Line Ahead” correspond most closely to the methods known more widely as Grid Searching. The Manual did not describe methods of “General Search” in detail. Sound Sweep was referred to but was not discussed; neither were other methods of searching primarily by sound. It advised the circumstances which might suit each General or Contact method but not in a comparative sense.

In essence, these sources provide, or refer to, search techniques that a search planner can use, but relatively little guidance on how to optimise their use for the circumstances of a search.

Further, search literature does not typically make a distinction between search strategy for finding a person alive versus a strategy for finding the MP in any condition. Hence the concept of Probability of Success (POS) is widely used without a definition of Success, the implication being that it refers to finding in any condition (which this paper terms POS_{fin}). Any analysis that focusses on POS needs to define Success. This paper applies two definitions, POS_{fin} and POS_{sav}, being the probability of saving the MP's life. The study assumes that the search planner will attempt to maximise POS_{sav} exclusively until a threshold at which probability of survival is low enough to justify switching to a focus on POS_{fin}; this study makes no assumption as to what that threshold should be.

This study explored the hypothesis that Voice Searching (as defined in Appendix 1) alone is a superior method to any other on-foot method that uses sight, voice, and hearing, for an MP who at time of disappearance was responsive and presumed wanting to be found. It did this in relation to POS_{sav} and POS_{fin}, while focussing primarily on POS_{sav}.

The very simple analysis that follows suggests that searching by voice might offer a such an advantage over searching by sight as to make the choice of methods for MPs who are responsive by nature more straight forward than is generally recognised.

At its most simplistic, a comparison of the effectiveness of searching by voice as a primary medium (Voice Searching) versus searching by sight as a primary medium (Line/Grid) can be made by a simple logic:

$P_{res} \times S_{voice} \approx POS_{sav(voice)}$

$P_{alive\ non} \times S_{line/grid} \approx POS_{sav(line/grid)}$

Where:

P_{res} is the probability that the MP is responsive at a given point in time,

S_{voice} is the speed of searching exclusively by voice measured by land area over unit time,

$POS_{sav(voice)}$ is the probability of saving the MP while searching entirely by voice,

$P_{alive\ non}$ is the probability that the MP is responsive at a given point in time,

$S_{line/grid}$ is the speed of searching exclusively by sight measured by land area over unit time,

$POS_{sav(line/grid)}$ is the probability of saving the MP while searching entirely by sight,

and for this purpose, it is assumed:

that Voice Searching never finds an MP who is unresponsive,

that Line/Grid Searching never finds an MP who is responsive, and

that all searching is at a POD of ~100% for a responsive or unresponsive MP respectively.

Suppose that on balance an MP would be expected to spend 4 times as long responsive as alive but unresponsive. Regardless of the rate of the MP's decline in health, the probability that the MP is responsive starts high but settles down to:

$P_{res} = 4 \times P_{alive\ non}$

Also suppose that:

$S_{voice} = 15 \times S_{line/grid}$

Then it follows that:

$POS_{sav(voice)} \approx 60 \times POS_{sav(line/grid)}$

According to this simple analysis, searchers will be about 60 times more likely to save the MP in any specified period of time if they are Voice Searching than if they are Line/Grid Searching. This is regardless of how long the MP has been missing. Any method which compromises the use of voice for greater use of sight, or vice versa, should offer a probability of saving the MP somewhere in between the Voice Searching and Line/Grid Searching.

This simple analysis ignores all the complexities of real life searching and search planning. To test the hypothesis with major complexities factored in, MS Excel was used to model a hypothetical search.

Method

The model examines a hypothetical search over four days. The hypothetical search planner has an opportunity to reassess strategy at the start of each day.

The Model

The Search Area

A hypothetical Search Area was divided into four segments with a total Probability of Area (POA) of 95%, the remaining 5% being in the rest of the world. This can be visualised as concentric circles or squares. However, shapes and alignments of segments are not relevant to the calculations that follow.

Strategy

The model allows the hypothetical search planner to select one or two search methods to be applied each day and across any segments. One permitted method is Line Searching to a target 100% POD for a prone, silent person. The other is a choice of Voice Searching, utilising the method described in Appendix 1, and Feature Searching; a method that combines/divides emphasis of sight and sound, as described in Appendix 1.

Calculating Probabilities

The model calculates the Probability of Success (POS) of a strategy at the start of the search and at the start of each day in view of the presumed failure of previous searching. It does this for the objective of saving the MP and again for the objective of finding the MP as quickly as possible, surviving or not.

To perform the calculations, the model uses the common method of assuming 100 MPs whose description and circumstances are identical, but who in every unseen respect are randomly different people. Counting the fates of the 100 MP's is arithmetically simpler than calculating conditional probabilities relating to a single person, is simpler to visualise, and it yields the same arithmetic outcomes.

The model tracks the number and distribution of remaining responsive MPs, alive unresponsive MPs and deceased MPs through the four days. This is equivalent to progressively recalculating POAs.

Real world complications and their treatment

All searchers are bi-modal.

'Bi-modal' refers to searching simultaneously by sight and radar (Koopman, 1946). Similarly, foot searchers are essentially bi-modal, searching by sight and sound.

The opening proposition ($POSsav_{(voice)} \approx 60 \times POS_{sav(line/grid)}$) assumed that Voice Searching achieves 100% POD by sound and nil detection by sight, and that Line/Grid searching achieves 100% POD by sight, and nil by sound,. Table 1 shows the Base Case assumptions used in the model, based target PODs of 100%.

	POD_{res*}	$POD_{non\text{-}res*}$	Team speed		No.Teams
Feature Search	90%	10%	0.25	km^2 searchable in one day, measured by voice reach	8
Voice Search	99%	5%	1.00	km^2 searchable by voice in one day	
Line Search (only)	99%	99%	0.067	km^2 searchable by sight in one day	
Line Search (following)	0%	99%	0.067	km^2 searchable by sight in one day	

**Probability of Detection for a responsive MP*
***Probability of Detection for an unresponsive MP*

Table 1 – Base Case assumptions: PODs, speeds and workforce

If there is any prospect of the MP being responsive at the outset, Line or Grid Searching will only be employed where a search method using sound has preceded it (Line/Grid Search (following)), thus resulting in an effective POD_{res} close to zero. In this analysis, Line/Grid Search (only) might have relevance later in a search if search planners have abandoned the prospect of the MP responding and are searching new ground.

Fast searchers are soon searching areas of lower Probability Density (PDEN) and therefore quickly become less productive.

Rarely would PDEN, a segment or sub-segment's POA per unit area, be uniform across the entire search area. Voice Searching is a faster method, so moves into areas where it is assumed that the missing person is inherently less likely to be. The model accounts for this by dividing the search area into segments of declining PDEN. Segments can have any configuration, however, those used in the model's base case (Base Case) (Table 2) are consistent with a bullseye pattern of concentric segments.

Segment	Area (km²)	POA
Segment 1	2	50%
Segment 2	6	25%
Segment 3	10	15%
Segment 4	14	5%
ROW		5%

Table 2 – Base Case assumptions: Segment areas and POAs

<u>*The MP's condition changes.*</u>

The assumptions about change in the MP's condition must describe how the MP is most likely to decline irrespective of the search, i.e. these assumptions will not be influenced by the progressive success or failure of the search.

Table 3 displays the hypothetical schedule of condition decline used in the Base Case. This assumes that organised searching commences half a day after the incident begins and that the ratio of responsive to unresponsive alive MPs is 4:1 and the daily survival rate is 70% of previous day survivors.

Average time spent responsive / time unresponsive but alive.	4
Days between LKTime* and SOD1	0.50

Timeline	Daily survival**
LKTime*	100%
SOD1	90%
SOD2	70%
SOD3	70%
SOD4	70%
EOD4***	70%

** LKTime - the known or presumed time of commencement of the incident.*
*** Daily survival - the proportion of MP's who were surviving at previous end of day who are still surviving at next SOD*
****End of Day 4*

Table 3 – Base Case assumptions: Responsiveness and Survivability

For the purposes of modelling, it was assumed that all MP's are physically stable throughout the duration of each day of searching, and that a proportion lose responsiveness or decease between the end of a day of searching and before commencement of the next day of searching.

These numbers are speculative, therefore sensitivity to these assumptions was tested by halving the relative time responsive and doubling the overnight mortality rate.

<u>*Mobility*</u>

Mobility statistics from *Lost Person Behavior*, (Koester, 2008) indicate that most of the MPs become immobile (but not necessarily unresponsive) within the first 24 hours of going missing, rendering mobility of doubtful significance.

Notwithstanding, two methods have been applied. The first is to take the PDEN of the unsearched part of each segment at the end of each day, then to move that number anywhere between 0% and 100% towards the average PDEN of the whole segment. 100% represents a world in which the MPs move rapidly and randomly within their segment to the maximum degree possible, and 0% is where no-one moves. 100% represents losing as many MPs to previously searched ground as random travel can allow and 0% loses none. The Base Case uses 20% for responsive and 0% for alive unresponsive MPs. It is arguable that a value should be attributed to unresponsive MPs, but a value of zero is more conservative to the study's conclusions. This method ignores inter-segment movement, which is presumably less likely to occur.

The second, simpler approach applies an arbitrary loss factor to all segments at each end of day. This represents the percentage of responsive MPs and alive unresponsive MPs who will have alluded searchers for the remainder of the search by relocating to a searched area. The Base Case uses 10% for responsive and 2.5% for alive unresponsive MPs.

These numbers are entirely speculative. However, sensitivity testing was conducted to establish whether the range of numbers that might conceivably reflect the true incidence of mobility impacting search outcomes would impact on the study's conclusions.

The impact of clues

"Clues" can be expected to impact results because they favour sight-based searching methods.

In actual searches, there are presumably many more clues, typically of low detectability, than are found. There are also many which are found without significantly altering the outcome, for example, by advancing the MP find by a non-critical hour. Additionally, there are false clues which impede a search. To mimic the mathematical impact of clues, the model accepts an input that represents the percentage of MP finds in which a clue was found first that resulted in an improved outcome, in terms of the MP being found alive versus deceased or being found deceased versus not found at all. It was estimated that this accounts for 10% of successful outcomes. Each such clue is treated as equally detectable as an unresponsive MP. Negative impacts from false clues were ignored. The model inserts a number of clues into the search area, distributing them in proportion to the POA of each segment. It adjusts this number until a search that employs methods in a particular hypothetical pattern finds 10% as many clues as the total number of MPs and clues found. This hypothetical pattern is referred to as the Base Strategy and will be defined shortly. The model retains that same distribution of clues regardless of which search strategy it is testing.

Data to support the clue frequency estimate will always be difficult to source. This is due to the impact of a particular clue to a search outcome is sometimes difficult to assess first hand and more so from reading search records. Sensitivity testing was performed using double this frequency, 20%.

Some MPs re-appear regardless of the search effort.

Some MPs find their own way to safety regardless of the search. More would do so if a search were not conducted. The relative efficiency of different search methods in some cases will affect the experiences of these MPs. Additionally, this will impact search statistics as a fast method might find an MP who, given more time, would have self-recovered. However, the choice of methods results in no significant difference to the fate of these MPs. For the modelling in this study, the 100 hypothetical MPs are assumed to be MPs who would never have self-recovered.

Combining Search Methods

The model enabled assessment of two important real-life factors that add overarching complexity. At this stage the model has assumed that:

- any technique that lies between Voice and Line in its emphasis has a POS somewhere in between.
- only one search method is used for the duration of the search.

To address the more complicated reality, the model assessed the POS of a search strategy that employs Feature Searching (a method that lies somewhere between the extremes of Line/Grid and Voice) in conjunction with Line Searching. The hypothetical search unfolds in the following way:

Day1 100% of skilled off-track searchers all employed by Feature Searching.

Lack of success creates concern that the MP is unresponsive close in and possibly alive. Therefore...

Day2 25% of those searchers are redeployed in some form of Line Searching close to LKP while 75% continue Feature Searching.

Concerns deepen, resulting in...

Day3 50%/50%

Day4 75%/25%

This pattern is intended to represent an unfolding of events, rather than a predetermined strategy but for simplicity will be referred to from this point on as the Base Strategy.

The Calculations

Using MS Excel, the following processes were performed.

Step 1

The 100 MPs were assigned to each of the four segments according to the opening POAs.

Applying the assumptions in Table 3, the model predicted the proportion of MPs who would be expected to be Responsive, Unresponsive Alive and Deceased at SOD1 within each segment.

Starting with the Base Case assumptions, the model calculated how much area can be searched in Day 1 using the assumptions in Table 1 if the workforce is employed entirely in Feature Searching. The model assigned the searching in the segment of highest PDEN of responsive MPs (Segment 1), continuing in Segment 2 if Segment 1 was completed within the day.

The model then calculated how many MPs in each condition would be found in each segment or sub-segment searched, and therefore how many MPs of each condition remain in each segment or sub-segment. The model recognises that some of these MPs would be found directly and some via clues. A separate tally of clues found and remaining was kept for each segment or sub-segment.

For the workforce deployed in this way, the numbers of MPs remaining in each condition in each segment were adjusted to factor in the drift of some surviving MPs onto ground already searched.

The numbers of MPs in each condition in each segment or sub-segment were then adjusted to reflect deterioration from one condition to the next in proportions dictated by calculations derived from Table 3.

Using these revised populations and the workforce allocation of Day 2 of the Base Strategy, all of these processes were repeated for Day 2. Only 75% of the workforce was assigned to Feature Searching which they continued in the segment or subsegment which offered the highest POS for that method that day. 25% of the workforce started Line Searching for the remaining MPs and clues in the already searched Segment 1.

For Day3 and Day 4, the model repeated the process, using a workforce split of 50/50 and 25/75. The Feature Searching was applied always to the segment or subsegment with the highest POS for Feature Searching and the Line Searching always continued in the areas of highest PDEN for survivors in the areas previously feature searched.

The POSs as at each SOD (assuming that the MP has not been found) could then be calculated for the Base Strategy.

POS_{sav} as at SOD1 = sum(MPs found alive Days 1,2,3,4)/100

In Table 6, this is the top left figure. The figure below it is

POS_{sav} as at SOD2 = sum(MPs found alive Days 2,3,4)/(100 – MPs found Day 1)

Likewise, POS_{sav} as at SOD3 = sum(MPs found alive Days 3,4)/(100 – MPs found Days 1,2), and

POS_{sav} as at SOD4 = sum(MPs found alive Days 4)/(100 – MPs found Days 1,2,3)

POS_{fin}s were calculated by substituting MPs found alive with MPs found alive or deceased.

The process was repeated for

- the Base Strategy but using Voice Searching instead of Feature Searching (Strategy 2)
- 100% Feature Searching only (Strategy 3)
- 100% Voice Searching only (Strategy 4)
- 100% Line Searching only (Strategy 5 (Line alone))
- Line as employed after Voice or Feature Searching. (Strategy 5 (Line following))

<u>Step 2</u>

The POSs calculated for SOD2, 3 and 4 thus far are based on different starting points and so do not provide valid comparisons because the most effective methods find and remove more MPs in the first day and so have less MPs to seek thereafter. To make valid comparisons for the later SODs, the model compared the POSs as at SOD2 for each alternative strategy if departing from the Base Strategy only at SOD2. It did the same for SOD3 and SOD4. For example, at SOD3: the search so far has been 100% Feature Searching on Day 1 and 25% Line / 75% Feature on Day 2; the model then compares going to 50% Line / 50% Feature for Day3 and so on as per the Base Strategy, as against:

- 50% Line / 50% Voice and so on, or
- 100% Feature thereafter, or
- 100% Voice thereafter, or
- 100% Line thereafter.

(Table 7)

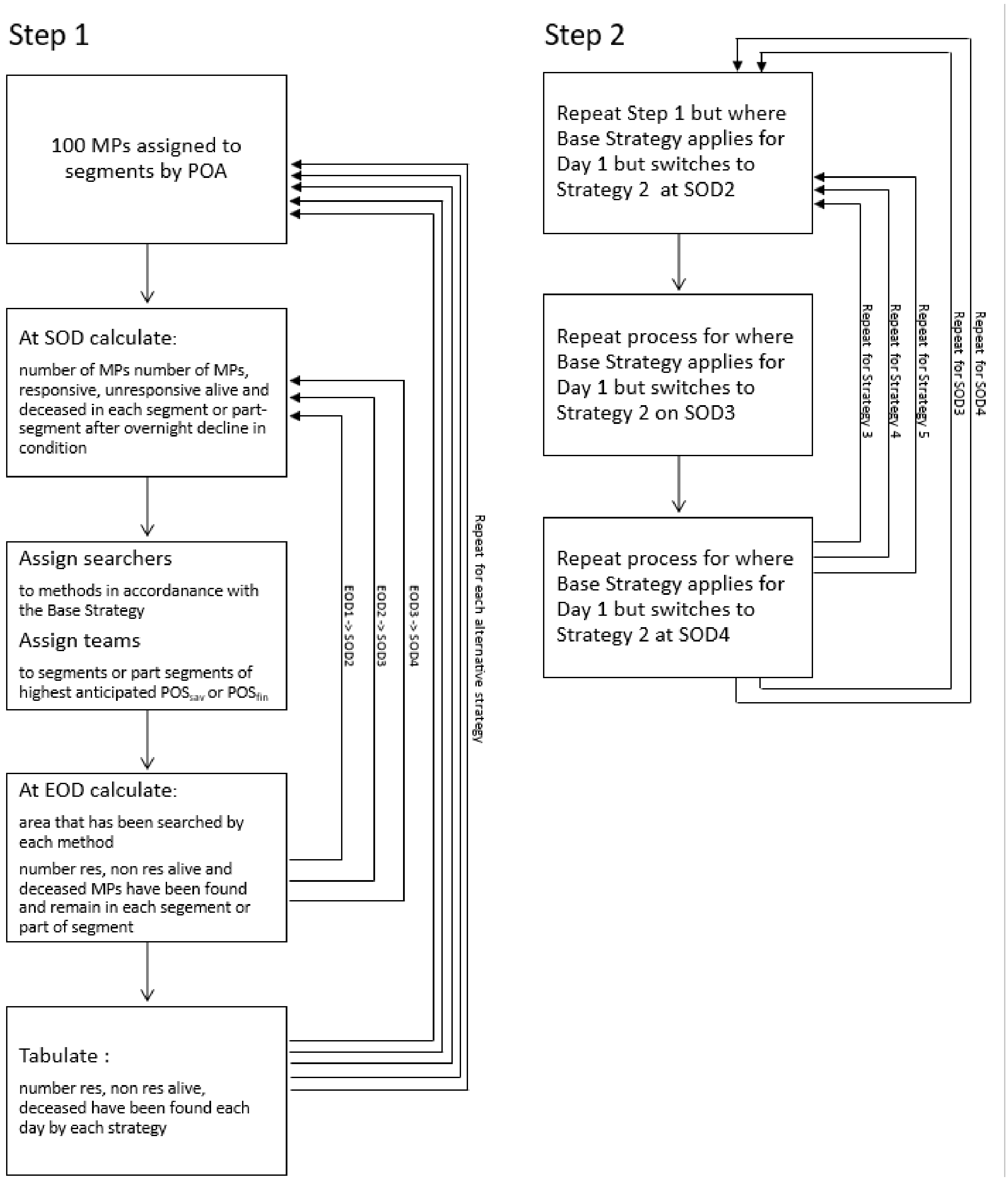

Figure 1 - Calculations

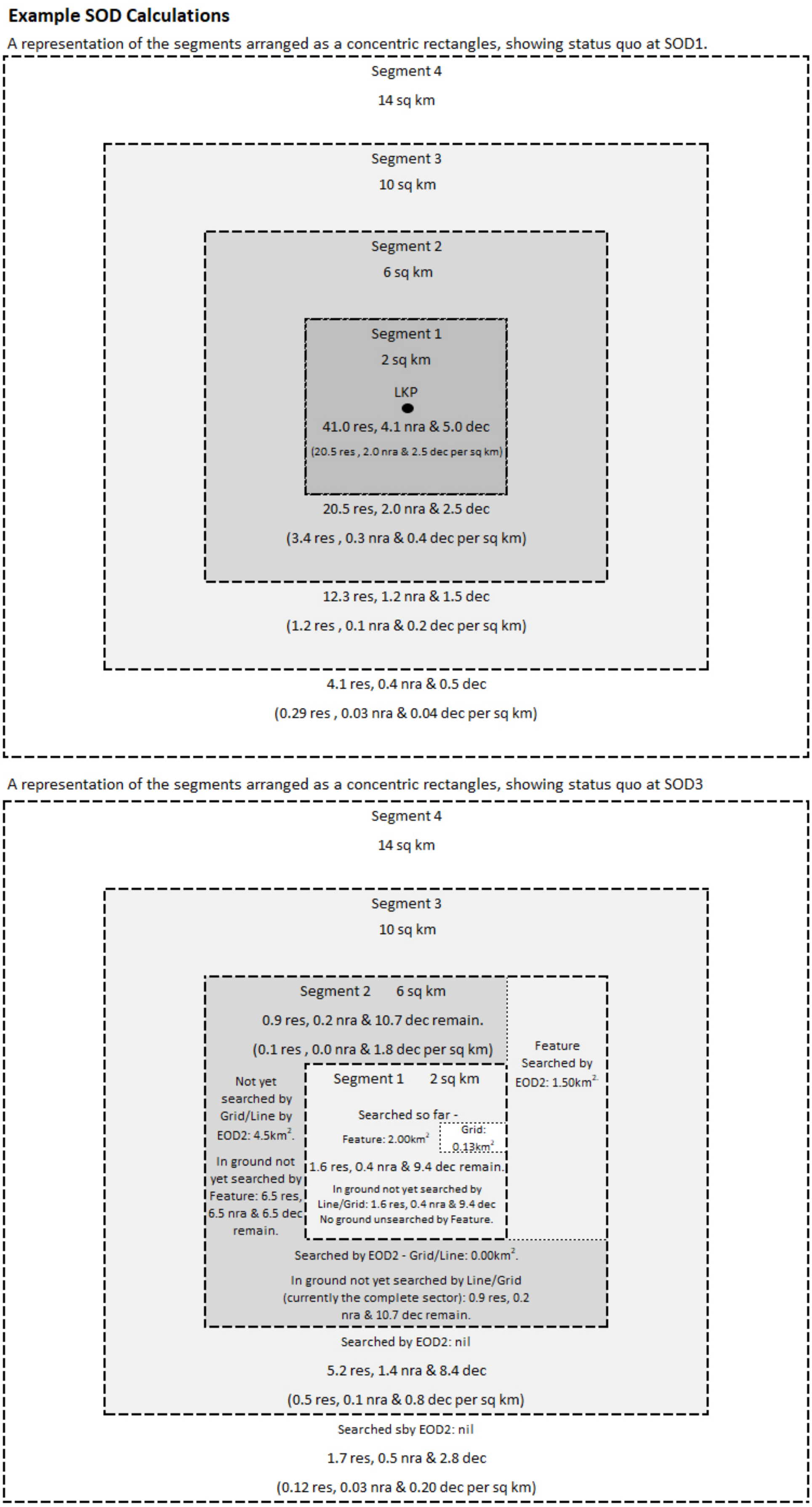

Figure 2 - Example SOD Calculations

Finally, because the purpose of the study was to assess the *comparative* value of each alternative at each stage of the search, the POS figures were re-expressed as values *relative* to continuing with the Base Strategy. (Table 8)

Results

Outcomes for 100 MPs

In a search area populated by 100 MPs all of whom fit the MP description and circumstances of disappearance but who are randomly variable all other respects, subject to the Base Case assumptions, the model predicts that the various search strategies will find MPs in the following numbers (Table 5).

MPs Found		Base Strategy Day 1 is Feature, but 25% workforce drawn into Line each day	Strategy 2 Base Strategy but with Voice replacing Feature Searching	Strategy 3 Feature Searching only	Strategy 4 Voice Searching only	Strategy 5 Line/Grid Searching (only) (where $POD_{res} \approx$ 100%)	Strategy 5 Line/Grid Searching (following) (where $POD_{res} \approx$ 0%)
Found Alive	Day 1	38.2	61.8	38.2	61.8	14.4	3.5
	Day 2	3.0	4.4	3.8	5.9	9.2	2.8
	Day 3	1.3	1.6	2.1	1.4	5.9	2.1
	Day 4	0.6	0.2	1.1	0.5	2.4	1.1
	Total	43.2	68.0	45.2	69.5	31.8	9.5
Found Alive or Deceased	Day 1	38.8	62.3	38.8	62.3	16.0	5.1
	Day 2	4.4	5.8	4.2	6.1	14.9	8.5
	Day 3	4.0	4.2	2.6	1.6	14.3	10.5
	Day 4	4.5	3.9	1.7	0.6	9.0	7.7
	Total	51.6	76.2	47.3	70.5	54.1	31.8

Table 5 – MPs expected to be found each day by each strategy.

POS_{sav} is the focus of this study. Figures for Found Alive or Deceased are included to demonstrate that the optimal strategy for resolving the search is not necessarily the optimal strategy for saving the MP.

Conversion to Remaining POS at each SOD

POS at a given SOD is the number of remaining MPs divided by the number of MPs remaining. The SOD1 POSs can be derived directly from Table 5 Totals. The figures for SOD2, 3 and 4 required Table 5 to be recalculated for each SOD (Table 6).

Remaining overall POS							
		Base Strategy Day 1 is Feature, but 25% workforce drawn into Line each day	Strategy 2 Base Case but with Voice replacing Feature Searching	Strategy 3 Feature Searching only	Strategy 4 Voice Searching only	Strategy 5 Line/Grid Searching (only) (where $POD_{res} \approx 100\%$)	Strategy 5 Line/Grid Searching F(following) (where $POD_{res} \approx 0\%$)
POS_{sav}	SOD1	43%	68%	45%	**70%**	32%	**10%**
	SOD2	8%	16%	11%	21%	21%	6%
	SOD3	3%	6%	6%	6%	12%	4%
	SOD4	1%	1%	2%	2%	4%	1%
POS_{fin}	SOD1	52%	76%	47%	71%	54%	32%
	SOD2	21%	37%	14%	22%	45%	28%
	SOD3	15%	25%	8%	7%	34%	21%
	SOD4	9%	14%	3%	2%	16%	10%

Table 6 – POS of each strategy, including POS remaining each day if search is not yet successful.

POS when switching to an alternative strategy on a later day

This paper began with a simple calculation that suggested that Voice Searching is 60 times more effective than Line/Grid searching for MPs who meet the premise (by nature can hear, can call, want to be found). By factoring in uneven PDEN, declining MP condition, clues and mobility, the model calculated the factor to be approximately 7, assuming the Base Case assumptions and that Line/Grid searching never precedes some form of searching by sound. This ratio is derived from the bolded figures in Table 6.

Taking the Base Strategy as the default, the model then calculated the POS of the remainder of the search as at each SOD if the strategy were to be switched at that SOD from the Base Strategy to one of the alternatives. SOD1 results (using the alternative strategy from the very start) are included for completeness. (Table 7).

	If considering a change of strategy from Base Strategy at	Remaining POS if search switches from Base Strategy to.. Strategy 2 Base Case but with Voice instead of Feature Searching	Strategy 3 Feature Searching only	Strategy 4 Voice Searching only	Strategy 5 Line/Grid Searching (only) (where POD_{res} ≈ 100%)	Strategy 5 Line/Grid Searching (following) (where POD_{res} ≈ 0%)
POS_{sav}	SOD1	68%	45%	70%*	32%	10%
	SOD2	25%	11%	29%	5%	3%
	SOD3	10%	6%	15%**	3%	2%
	SOD4	3%	2%	6%	1%	1%
POS_{fin}	SOD1	76%	47%	71%	54%	32%
	SOD2	38%	14%	30%	28%	26%
	SOD3	22%	8%	17%	20%	19%
	SOD4	11%	3%	8%	11%	10%

Table 7 – POS of switching from the Base Strategy to alternative strategies at each SOD

Using the asterisked (*) figure as an example, if Voice Searching is used exclusively from the start of searching, this figure will be the starting POS_{sav} of searching by voice for as long as it takes, up to a limit of 4 days. Using the double asterisked (**) figure as an example, if the search unfolds as per the Base Strategy for Days 1 and 2, this will be the POS_{sav} of searching by voice from SOD3 to the end of Day 4.

Comparing POS of alternatives with Base Strategy

The model then *compared* the POSs of switching on any day to one of the alternatives, as against continuing with the Base Strategy. The results are displayed in Table 8.

	If considering a change of strategy at.	Comparison with Base Strategy at each Start of Day: Strategy 2 Voice & Line : Base Strategy	Strategy 3 Feature only : Base Strategy	**Strategy 4 Voice only : Base Strategy**	Strategy 5 Line/Grid only : Base Strategy	Strategy 5 Line/Grid following : Base Strategy
POS_{sav}	SOD1	1.6 : 1	1.0 : 1	1.6 : 1	0.7 : 1	0.2 : 1
	SOD2	3.0 : 1	1.4 : 1	3.5 : 1	0.6 : 1	0.3 : 1
	SOD3	3.0 : 1	1.7 : 1	4.3 : 1	0.7 : 1	0.5 : 1
	SOD4	2.7 : 1	2.1 : 1	5.8 : 1	0.8 : 1	0.6 : 1
$POSf_{in}$	SOD1	1.5 : 1	0.9 : 1	1.4 : 1	1.0 : 1	0.6 : 1
	SOD2	1.8 : 1	0.7 : 1	1.5 : 1	1.3 : 1	1.2 : 1
	SOD3	1.5 : 1	0.5 : 1	1.1 : 1	1.3 : 1	1.3 : 1
	SOD4	1.2 : 1	0.4 : 1	0.9 : 1	1.2 : 1	1.2 : 1

Table 8 – The comparative values of switching strategy versus beginning with/continuing with the Base Strategy as at each SOD.

Sensitivity Testing

It is acknowledged that the key assumptions of Base Case are just estimated medians. To test the robustness of the results, sensitivity to significant variations in the assumptions was tested, (Table 9). Sensitivity testing has been conducted for all results. The test results in Table 9 refer to variations in Base case assumptions applied to the comparative value in terms of POS_{sav} of Voice Searching for the duration of the search versus the Base Strategy.

Sources		Sensitivities			
			POS_{sav} ratio at SOD1		
Assumptions	*Source of base assumption*	*Change from base assumption*	*was*	*becomes*	*Significance*
Clues	Speculative	10% -> 20%	1.61 : 1	1.55 : 1	minor
Mobility	Speculative	All factors increased x 2.5	1.61 : 1	1.62 : 1	minor
Time responsive : time alive unresponsive	Speculative	4 -> 2	1.61 : 1	1.60 : 1	minor
Condition decline	Speculative	Daily Survival 70% -> 40%	1.61 : 1	1.61 : 1	minor
Relative speeds of competing methods	Analysis of incident data (Appendices 2 & 3)	Voice : Line 15:1 -> 7.5:1 Voice : Feature 4:1 -> 2:1	1.6: 1	1.3 : 1	sensitive. Suggests a search planner might question the study conclusions if he/she believes Voice Searching at given POD for a responder is no more than about 4 times the speed of Line Searching, to same POD for unresponsive MP, e.g. in noisy weather
Relative PODs	Searcher / author estimates (Appendices 2 & 3)	POD_{res} Feature 90%-> 45% Voice 99% ->45% Line - unchanged	1.6 : 1	1.5 : 1	sensitive. But not sufficient to cast doubt on the study conclusions. This also roughly equates to an MP being 50% responsive by nature.
Workforce v Land Area	Arbitrary	8 teams -> 4 teams (which is also equivalent to doubling the search area)	1.6 : 1	2.0 : 1	Sensitive. But simply reflects that the effect loses significance if the workforce is large enough to search the entire area in a single day.

Distribution of PDEN	Arbitrary	Bullseye -> uniform PDEN	1.6 : 1	5.5 : 1	v sensitive. But indicates that the study conclusions will be understated in relation to a very large search area
	Koester, 2008	Bullseye -> LPB Hiker*	1.6 : 1	2.0 : 1	sensitive. But not sufficient to cast doubt on the study conclusions
	Arbitrary	Bullseye -> Intense bullseye	1.6 : 1	1.4 : 1	sensitive. But not sufficient to cast doubt on the study conclusions

**The distribution of MPs when found, from* Lost Person Behavior*, (Koester, 2008), data for Hikers.*

Table 9 – Sources of Base Case Assumptions and Sensitivity of Results to Assumptions

Discussion

Interpretation of results

By comparing strategies, Table 8 demonstrates that:

- searching by voice offers a strong advantage over searching by sight and over any method or strategy combining voice and sound in any search matching the premise (MP is responsive by nature, wants to be found).
- that, if saving life remains the objective, the case for searching by voice does not diminish with the passage of time, notwithstanding the diminishing probability of responsiveness.
- other strategy comparisons differ significantly depending on the objectives of the search (finding versus saving), demonstrating a broader principle that optimising POS depends on specifying the objective.

It follows that searching by voice should be the favoured method for all searchers who are capable of executing such a method systematically. However, there may be strong and well-defined reasons to do otherwise.

Limits of application

If there is a very clear reason to favour searching by sight, this study's conclusions might not hold. Exceptions include:

Not Meeting the Premise

It is acknowledged that the findings are limited to searches which are predicated on the MP being by nature responsive to some degree.

Workforce expertise

The study assumes that there is a workforce capable of being deployed searching by voice in a safe and accountable way.

Clues near LKP

Common sense would suggest that the value of searching for clues in the immediate vicinity of LKP can outweigh the value of searching by sound. The model is not sufficiently fine-grained to indicate whether the potential value of searching specifically for clues in the immediate vicinity of LKP outweighs the value of searching by sound.

Reaching the limits of the search area

A limitation unstated earlier in this paper is that occasionally, it might be possible to search by voice to ~100% POD to the limits of the Search Area and must therefore cease.

Exceptions do *not* include that the MP will likely have been rendered unresponsive by the duration of their ordeal.

Robustness of results

The conclusions of the study are open to question to the extent that its numerical assumptions are speculative or are likely to be dependent on a search situation. To test the robustness of the conclusion that Voice Searching is superior to Line and intermediate methods, sensitivity tests were conducted.

In each case, a single assumption or a group of related assumptions was changed to test the impact that the imprecision of the Base Case assumptions has on the study conclusions. (Table 9)

The sensitivity tests indicate that the study's broad conclusions are robust, despite the relative lack of data to support the numerical assumptions.

There is some sensitivity to the key assumptions related to relative speeds of search methods. However, only if the observations presented in Appendices 2 & 3 were extremely unrepresentative of average search experiences would that sensitivity cast doubt on the study conclusions.

Objectives of the search

There are two issues relating to search objectives on which the reviewed literature is silent.

- That selecting optimal search methods and strategy can depend on whether the objective is to save the MP or to resolve the search as soon as possible without regard to the MP's possible condition.
- How to decide when the saving objective should be abandoned, given that the MP's survival prospects will never be absolutely zero.

The apparent absence of LandSAR wide protocols means that this modelling cannot predict when in the hypothetical search the objective should change. Hence the numerical results have been presented as two parallel tables (POS_{sav} and POS_{fin}), rather than measuring an overall POS.

Although it was not the focus of the study, it is worth noting that the importance of making POS_{sav} the exclusive objective of a search while survival remains in prospect is demonstrated by the results tables.

Definition of responsiveness

The definition used in this study is not the usual medical definition because, for the purposes of searching, merely being able to whisper is of no aid to a searcher. Its imprecision is acknowledged, but the sensitivity of results to this imprecision can be estimated from Table 9. For example, if the MP by nature has about half the average carry of a person's voice, this would roughly equate to halving the speed of Voice Searching.

Degrees of responsiveness

The findings suppose that every MP is completely responsive at time of disappearance. That is, if the MP hears a searcher, they will reliably reply.

Therefore, if the MP is known to be by nature unresponsive, Voice Searching or any other sound-based method becomes ineffective. But the reality will often be less clear. If an intellectually impaired MP, is described as "unresponsive", that might mean something less than completely unresponsive. A person known to be depressed might be suspected of being in the wilds to commit suicide and therefore not motivated to respond but might be simply lost. Voice Searching becomes marginal where the probability of innate responsiveness falls below a certain point. Further investigation is needed, but at this stage, a rough exploration of this question indicates that the crossover is of the order of 30%. That is, on average, if the MP is thought to be by nature more than about 30% likely to be responsive at time of disappearance and all searchers are considered capable of searching by voice, Voice Searching should be the priority.

Expert medical advice

The study employs an abstract assessment of the relative probabilities of responsiveness, living unresponsiveness and death. The underlying supposition is that for want of better knowledge, the search planner can only assume a general pattern of decline. In reality, most search planners will have access to expert medical advice based on the particulars of the individual, the weather and the terrain. It would be natural to assume that when that advice indicates that the most probable timeline of decline of the MP in question would put that MP in the alive/unresponsive state, searching should focus on the immobile unresponsive MP. However, Voice Searching will normally continue to offer the highest probability of saving the MPs life. That is because the probability of the MP being responsive will still be significant, even if small, compared to the probability of the MP being alive/unresponsive. Suppose for example that the probabilities at that point are P_{res} 20%, $P_{alive\ non}$ 60%, P_{dec}: 20%, the relative effectiveness of sound over sight overwhelms those odds.

Other search methods

There are other sound based methods in use around the world. Many involve whistles. Any sound based method that can be shown to be more effective than the Voice Searching method considered in this study, will provide an even greater advantage over Line/Grid Searching or intermediate methods.

Approximations to search theory

Search literature contains many references to repeat low POD searching and some readers might question the use of 100% target PODs in this analysis.

The advantage of repeat low POD searching is that the first sweep is more efficient in terms of POD per searcher. While it is possible to justify this with mathematical theory, it is more simply viewed as improving productivity by reducing the overlap between each searcher. While each repeat sweep will then have a progressively lower POD given the growing *im*probability that the MP is there, the repeat sweeps can eventually achieve a high cumulative POD. Because the MP has a limited life expectancy, there is advantage is in the timing.

The model has the capacity to examine repeat low POD searching, if the PDEN calculations justify repetition. But this adds considerable and unnecessary complexity to comparisons. Exactly at what target POD that approach is optimised is a complex matter, requiring an algorithm that balances the pure mathematical advantage of separating searchers or search teams almost infinitely versus the logistical cost of increasing separation and the unpredictable degree to which searcher paths on any repeat sweep will be independent of any previous sweep paths.

A target POD often suggested is approximately 60%, as if perhaps to suggest that the balance between mathematical theory and practical considerations is optimised at that POD, or perhaps in reference to the unrelated POD within one Effective Search Width as defined by Koopman, 1946. If all methods used in this study were to have their PODs equally reduced to 60%, the comparison of search methods would change slightly because of MP mobility issues, but the change in POS comparisons, and therefore conclusions, would be slight.

Further, to keep complexity manageable, the model takes a simplified approach to the concepts of POD, ignoring the concepts of Cover and Effective Search Width. The author believes this approach is sufficiently accurate for the purpose.

Limitations of the study

The nature of modelling

A model must always approximate the complexities of real life. There is almost limitless scope to include minor influences and to refine calculations. But it is always necessary to limit refinements to those that have a prospect of significantly impacting outcomes.

The conclusions of this study are simple and broad and so it is the author's opinion that all factors of a magnitude that will impact on the findings have been considered.

Benchmarking of inputs

The relative speed of search methods is a critical assumption. Objective observations require different methods to have been used by similar teams in very similar terrain and weather conditions, preferably without the searchers knowing that their speed will be measured. This happens on a real-life search only by rare chance. A mock search for the purpose would be difficult to construct and would be beyond the resources of this study. The incident analysed in Appendix 2 was one such rare real-life occurrence and was the inspiration for this study. The incident analysed in Appendix 3 is the only example available to the author that is close to providing a direct comparison of Line/Grid with Voice. More data might come to hand with the passing of time.

Estimating instantaneous POD

The POD's used in the Base Case are estimates made by the author who was on the ground in three of the four searcher groupings described in Appendices 2 & 3.

The low POD figures are necessarily very subjective and the near 100% figures will invite scepticism. In relation to the latter, it needs to be noted that the near 100% PODs were the target PODs of the tasks and the speeds of operation were the variable, leading to a high confidence in the POD's achieved. Nevertheless, the disputability of the POD's simply highlights that the examples used for Base Case calculations provide just single data points and that this work would be strengthened by more field data.

Future research

Further research into the assumptions

While sensitivity testing suffices for extensive data in this study, it would be affirming to have more data that informs the Base Case assumptions and to understand how much those factors vary between regions: comparative search speeds and PODs; typical timelines of losing condition through losing responsiveness and on to decease; and the statistical impact of clues.

Establishing a base case scenario for further study

Published data does not provide enough information to establish a plausible and defensible base case that reconciles with known statistical outcomes. This and similar studies could be enhanced by further work that establishes all the parameters of a statistically average or median missing person situation and search outcome.

Establishing how innately unresponsive the MP must be before favouring sight based methods

A rough calculation suggests that the study conclusions hold if the MP is thought to have been more than somewhere around 30% likely to respond at time of disappearance. Further modelling should provide a more reliable number for this threshold.

Establishing the approximate limits of the area worth searching off-track by foot

A limitation of these findings is that Voice Searching is of little value once the Search Area has been searched to its realistic limits. Implicitly, those limits will be where the opening PDEN falls below a certain value. This study would be enhanced by further modelling to identify the PDEN that should define the boundaries of the area worth searching.

Conclusions

1. In almost all searches where the MP is by nature capable and willing to respond, notwithstanding their presumed physical decline, off track searching should be conducted with the greatest possible emphasis on detection by sound.
2. While such an MP's survival remains in prospect, tasking skilled searchers to employ methods that assume that the MP has become unresponsive will compromise the probability of saving the MP, even though the MP might still be alive but unresponsive.
3. The model confirms an effect that optimising strategy is dependent on whether the objective of the search at any given time is to save the MP's life or to find the MP alive or deceased as efficiently as possible.
4. While the objective is to save life, the advantage of searching by sound over searching by sight or an intermediate method does not diminish with the passage of time.

Conclusions 1) and 2) are represented diagrammatically in Figure 3.

<table>
<tr><td colspan="2"></td><td colspan="2">|------------------------------Timeline------------------------→</td></tr>
<tr><td colspan="2"></td><td>While reasonable prospect of survival</td><td>Once no reasonable prospect of survival remains</td></tr>
<tr><td colspan="2"></td><td><u>Objective</u>
Find alive</td><td><u>Objective</u>
Find asap in any condition</td></tr>
<tr><td rowspan="2">Situation</td><td>All other situations</td><td>Search by sound
(all suitable personnel, max use of sound, sight detection incidental)</td><td rowspan="2">Search by sight</td></tr>
<tr><td>At the outset, MP is by nature very likely unresponsive
or
environment masks sound
or
Voice Searching has been completed</td><td>Search by sight</td></tr>
</table>

Figure 3 - Decision Matrix

Acknowledgements

The author would like to acknowledge the Victoria Police Search and Rescue Squad for access to GPS tracks, in particular to Jason Ball who was a willing and receptive sounding board and Greg Paul for his openness to new perspectives.

Thanks also to Robert Koester for pointing me in the direction of relevant literature and data and other matters.

About the author

Rod Costigan has been volunteering for remote area searches in Victoria, Australia, for over 40 years. He has enjoyed a career in banking and finance and business and now guides wilderness expeditions in northern and central Australia. His work in financial derivatives included extensive modelling.

Abbreviations and Terms

Base Case	The hypothetical situation that is used in this study for the purpose of comparing response outcomes.
Base Strategy	A particular combination of Feature Searching and Line Searching, against which other strategies are compared in this study.
EOD	End of Day.
Feature Searching	Searching along gullies or crests, by a combination of sight and calling/listening as described in Appendix 1.
Grid Searching	Several searchers searching by sight in a line approximately perpendicular to the direction of travel. Spacing of individual searchers is fixed.
Line Searching	Several searchers searching by sight in a line approximately perpendicular to the direction of travel. Spacing of individual searchers is fluid and determined by a target POD as described in Appendix 1.
Line/Grid Searching	Line or Grid Searching where for the purpose of this paper the distinction is immaterial.
LKP	Last Known Point – the latest confirmed location of the missing person. For this study, synonymous with Point Last Seen.
MP	Missing Person.
P_{res}	Probability that the MP is responsive at a given point in time.
$P_{alive\ non}$	Probability that the MP is alive but no longer responsive at a given point in time.
P_{dec}	Probability that the MP is deceased at a given point in time.
PDEN	Probability Density – the probability that an object or person (eg an MP or a clue) lies within a defined area, divided by the measure of that area.
POA	Probability of Area – the probability that something (e.g. an MP or object) is within a defined area.
POD	Probability of Detection - the likelihood of locating an object or person.
POD_{res}	Probability of detecting a responsive MP in a completed task by a given method if the MP is in the area searched.
$POD_{non\text{-}res}$	Probability of detecting an unresponsive MP in a completed task by a given method if the MP is in the area searched.
POS	Probability of Success, usually referring to the potential outcome of the entire operation. In this paper, is also applied to each day of operation.
POS_{fin}	Probability of Success, where Success is defined as finding the MP, alive or deceased.
POS_{sav}	Probability of Success, where Success is defined as finding the MP alive (saving).
$POS_{sav(Voice)}$	POS_{sav} of searching entirely by Voice Searching.
$POS_{sav(Line/Grid)}$	POS_{sav} of searching entirely by Line or Grid Searching.
S_{voice}	Speed of Voice Searching.

$S_{line/grid}$	Speed of Line/Grid Searching.
Segment	An arbitrary division of the search area.
SOD	Start of Day.
Sub-segment	Part of a segment, used to refer to the part of a segment that has been searched when the rest has not, or vice-versa.
Voice Searching	Searching with maximum possible emphasis on calling and listening as the means of detection in the manner described in Appendix 1.

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Appendix 1 - Description of Search Methods

The Base Case assumptions speeds and PODs used in this study were based on actual search records (See App 2 & 3). There were three methods in use.

Voice Searching

The term, Voice Searching, has been used here as follows. A team is given a defined area on the map to search to a target 100% for a responding MP. The group, ideally of 2 members, uses each other's voices to judge the carry of voice in the environment and so to space themselves and their contiguous sweeps to ensure that they have travelled and listened to everywhere within the reach of someone calling with moderate vigour (or loader or softer as search control might specify).

Appendix 2 includes the tracks of two searchers who were assigned an area and asked to 'clear' the area for a responding MP. This site lent itself to having the searchers follow features, mostly with one on a spur and the other in the adjacent gully. (Hi-Viz clothing, UHF radios and a meeting point, mitigated any risk of separation). The two searchers were able to consistently assess the carriage of voice by hearing each other and were free to adjust their separation and route to allow for competing sources of sound, e.g. running water, wind. A second task was undertaken but with search planners assigning lines of searching, which were not ideal for this technique - hence a hole in coverage - but which still produces valid data for this study. It is generally supposed that ridgelines and streamlines have a higher PDEN than the spaces between them. Data from Koester, 2008 indicates that about 42% of found Hikers were off track and of these 29% were close to drainage lines. For the purposes of comparing methods, it is important to note that both methods examined in Appendix 2 enjoyed that advantage more or less equally. In executing this task, the Voice searchers interpreted "responding" as being able to call out "with moderate vigour".

The tracks in Appendix 3 are of five searchers, the same individuals who conducted the line search described above. They were separated into two groups (2 and 3 searchers). Each group was assigned one of two contiguous areas to search. Each group was asked to search its area to 100% POD for a responding MP, meaning that they were to report back to their satisfaction that their voices reached every part of their assigned area and that they passed within earshot of any person calling back with "moderate vigour".

Feature Searching

The method referred to in this paper is one where two or more searches follow a line feature, typically following gullies and streams in one direction and returning via spurlines. Suppose that a team of two is following a gully. The searchers will walk either side of the gully at whatever separation ensures a high degree of confidence that the MP is not lying motionless between them. They also scan to the outside of that band. Both searchers will deviate to investigate impediments to line of sight. Both searchers will also be calling and listening, achieving a band of voice coverage of indeterminate with. In some dense gullies, sight POD might fall well below 100% in the interests of time. On the spurs, sight POD might be close to 100% but to a breadth that may be inconsistent or may be to a consistent breadth but an inconsistent POD. This method leaves large gaps in visual coverage between neighbouring sweeps and is open to leaving unrecorded gaps in voice coverage between the features and indeed unnecessary overlap. It can be performed with larger search groups to widen the breadth of the sight searching.

Appendix 2 displays the tracks of three pairs of searchers who had been assigned lines to follow along gullies and adjoining spurs.

Line/Grid Searching

This paper assumes a method of line searching as follows. A team walks in a line roughly perpendicular to the direction of travel. Usually, the searcher at one end follows one boundary of the allocated area, the next searcher spaces him/herself from the first searcher and so walks slightly behind the first. The third works off the position of the second and so on. The last searcher in the line ties maker tape along their path. Each searcher contracts the spacing from the adjoining searcher such that the subject (MP or clue of a specific dimension) is certain to be seen and expands the spacing where sightlines are long. Each searcher deviates momentarily from their line whenever necessary to search where sight lines are broken by occasional fallen wood, ferns, etc. When the far boundary of the tasked area is reached, the line flips around the trailing searcher who then leads by following his/her own tapes.

The term, grid searching, usually applies to the searchers following strictly parallel straight lines. This paper assumes numerically similar outcomes.

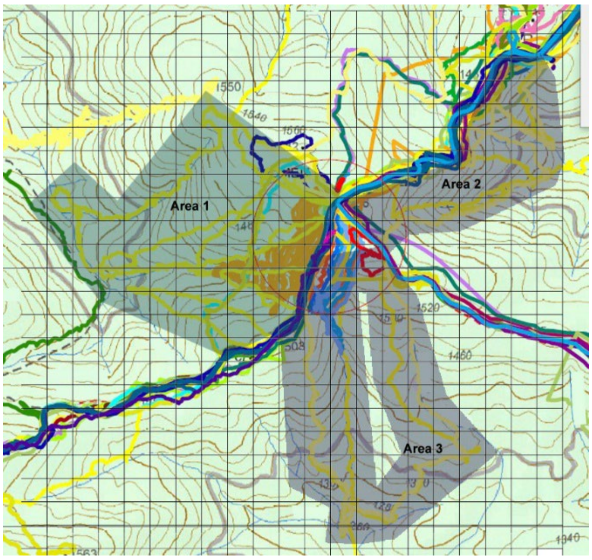
The tracks in Appendix 3 are of a group of five searchers following a broad steep spurline on which there was reason to believe a shoe had been loosely discarded. At slight variance to the above, the leader navigated the central line with two searchers on each side. Searchers at each end taped their paths to facilitate later sweeps as might be required. On each side of the leader, the separation of searchers expanded and contracted as necessary to cover the maximum breadth of ground while ensuring – to the satisfaction of the searchers - 99% POD.

The outcomes have been scaled arbitrarily for an equivalent search for a reclining motionless MP. The factor is an estimate based on an assessment of the vegetation at that location. (The shoe was subsequently found on a different spur.)

Appendix 2
Voice Searching and Feature Searching Strategy Study

Figure A2.1 is a de-identified record from an actual search.

The searcher tracks inside the shading were all recorded on the same day. Area 1 was searched by Teams A, B and C (two members each) who searched using the feature searching routine described in Appendix 1.Area 2 and 3 were searched by Team D who switched early to the voice searching method described in Appendix 1.



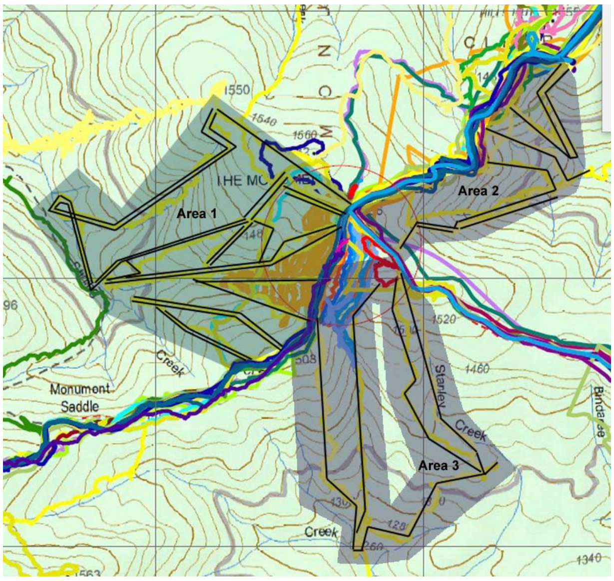
Yellow lines within grey shaded Area 1, measuring ~76 Ha,are of Feature Searching.

Yellow lines within grey shaded Areas 2 & 3, measuring ~96 Ha,are of Voice Searching.

Grey shading represents estimated reach of searching for a responding MP.

(100m grid)

Fig A2.1 - Comparing Land Area searched by Voice Searching and Feature Searching in Comparable Terrain



Yellow lines within grey shaded Area 1are of Feature Searching.

Yellow lines within grey shaded Areas 2 & 3 are of Voice Searching.

Black lines represent estimated distance walked over. Two searchers one behind the other is a single line.

(1000m grid)

Fig A2.2 - Comparing Distanced Walked by Voice Searching and Feature Searching in Comparable Terrain.

		Teams A, B and C collectively Area 1 (Feature Searching)	*Team D Total of Areas 2 & 3 (Voice Searching)*	*Relative speed*	*POD for area searched (Responding MP)*	*POD for area searched (Unresponsive MP)*
From Figure A2.1	*Approximate area searched **by voice***	76 Ha	96 Ha		**100%**, but acknowledging that the MP could enter the area after searching.	unknown
	Per searcher	12.3 Ha	48 Ha	12.3/48 =**0.26** **(or 3.9)**		
From Figure A2.2	*Approximate area searched **by sight** (assume10m band pp)*	10.6km x 10m = 10.6 Ha	7.5km x 10m = 7.5Ha		**unknown** Possibly 100% because of the close search tasking, but actually unknown.	unknown
	Per searcher	1.8 Ha	3.8Ha	1.8/3.8 =**0.47 (or 2.1)** but acknowledging that the approximating factors that the voice searchers were not as thorough with sight searching but that their effective width was not reduced by overlap.		

Table A2.1 - Calculating Relative Speeds of Feature Searching and Voice Searching

This rough comparison suggests:

- that the team searching by **voice** for a **responding MP** searched about **four times** the area per searcher than the teams searching for a responding MP by Feature Searching and with the advantage of a quantifiable outcome
- that, surprisingly, the probability per searcher of finding an **unresponsive MP by sight** was **~2.1 x greater for the voice searchers** than the feature searchers.

Approximately comparable PDENs have been assumed.

Appendix 3

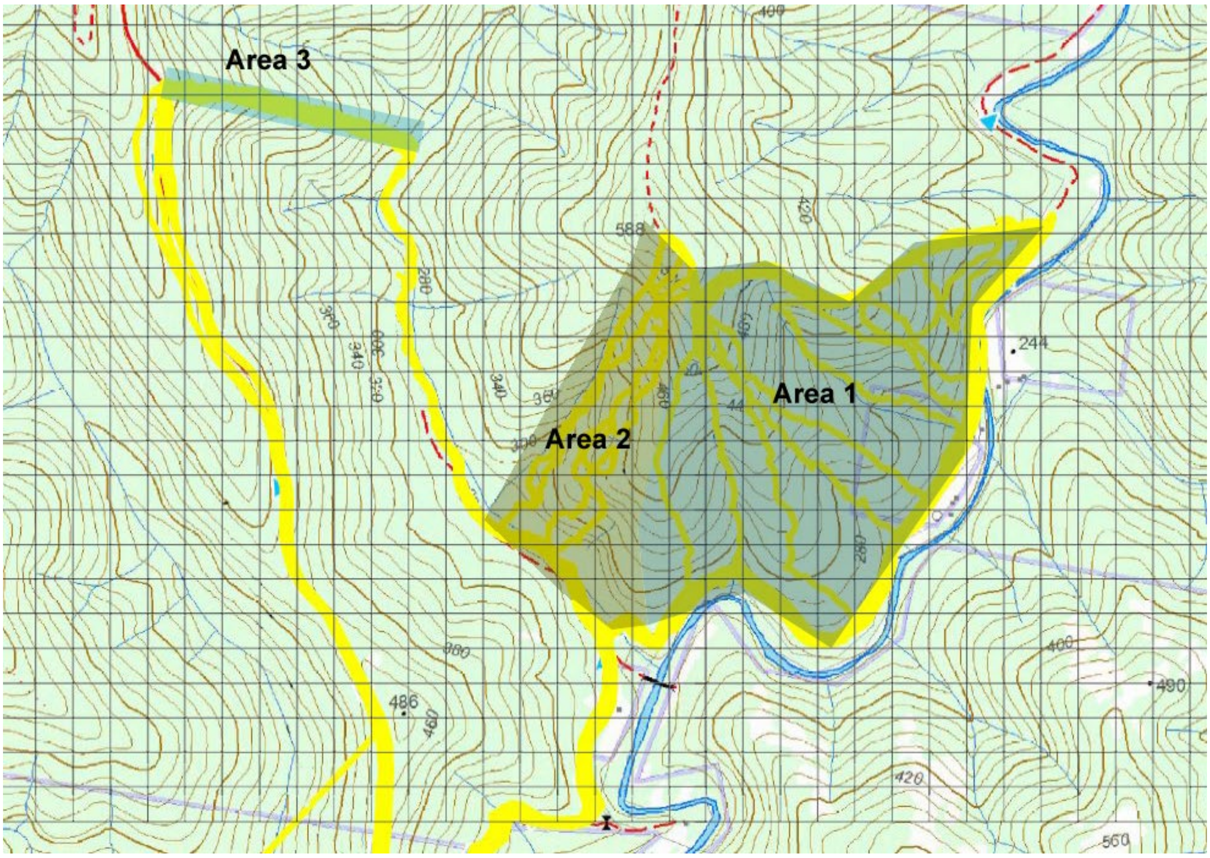
Voice Searching and Line Searching Strategy Study

Figure A3.1 is a de-identified record from another actual search.

Table A3.1 uses tracks were recorded by the same group of five searchers on the same day in almost identical terrain, all downhill.

Area 1 was done by a team of two as a voice search. Simultaneously, Area 2 was searched by a team of three.

Later the two teams combined to perform a line search of Area 3. This was a search for a brightly coloured shoe that there was reason to believe that MP might have discarded on this spur line. In Table A3.1, an estimation has been made by one of the searchers (the author) of the breadth that the team would have searched to the same thoroughness and speed if the subject had been an immobile unresponsive person.



(100m grid)

Yellow lines within grey shaded Areas 1 & 2 are of Voice Searching.

Grey shading of Areas 1 & 2, measuring ~110 Ha, represents estimated reach of searching for a responding MP.

Yellow lines within grey shaded Area 3 are of Line Searching.

Grey shading of Area 3, measuring ~4.5 Ha, represents estimated reach of searching for an unresponsive MP.

Fig 3.1 - GPS tracks of Voice Searching and Line Searching in Comparable Terrain

		Area 1&2 *Voice Searching*	*Area 3* *Line searching by sight (for blue shoe in mostly clear ground surface, between tightly crowded saplings)*	*Relative speed*
From Figure A3.1	*Approximate area searched*	110Ha	750m x 60m = 4.5Ha	.
	If subject had been unconscious person, extra breadth:		x 2 = 9.0Ha	
	Time taken	1.75 hrs*	2 hrs	
	Ha per searcher per hour	12.6 Ha / p / hr	0.9 Ha / p / hr	**14:1**
	PoD for area searched (Responding MP)	**100%**, but acknowledging that the MP could enter the area after searching	**~98%**	

Table A3.1 - Calculating Relative Speeds of Line Searching and Voice Searching

This rough comparison suggests:

- that the team searching by **voice** for a **responding MP** can search about **fourteen times** the area per searcher per hour for the responding MP than a line search for an **unresponsive MP** in that particular terrain.