

# **Search Management**

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# Probability of Area

Pete Roberts and Dave Perkins of Northumberland National Park Search & Rescue Team in the UK are world acknowledged authorities on the complex theories which form the basis for modern search management. In fact much of what appears to be complex is really very simple and with the advent of computers and dedicated search programs in SAR even the horrifying looking calculations can be carried out easily. Pete & Dave have been clarifying aspects of Search Management in a series of articles which began in Issue 6 of Technical Rescue Magazine. In the following articles published in issue 11 and the forthcoming issue 13 they move deeper into the realms of search mythology dispelling the mysticism which surrounds a subject synonymous with acronyms and numbers:

In an earlier article we defined Probability of Area (POA) as "the chance that the subject or clue is in the search area". What we meant by this was that once you have divided up the area you are going to search into manageable sized segments, then you can apply a number to each of those segments, usually in the form of a percentage. This percentage is your estimation of the likelihood that the missing person (or clue) is in each of those segments. As with POD this may at first seem simple and straightforward. However we will look at a simple example to illustrate some of the problems and pitfalls.

Suppose that by looking at a map we have decided what overall area we intend to search to start with (i.e. in the Initial Phase), we have then divided this up into a number of segments using features which are easily found on the ground, for example walls, fences, streams or the edges of woodland. Suppose that there are five of these segments (A, B, C, D & E), although in reality there would be many more. The POA's for each of these segments will be our estimates of how likely we think it is that the missing person is in that particular segment.

Here comes the first problem: obviously the missing person is somewhere so overall our POA's must add up to 100%. But we cannot be absolutely sure that they are in one of our segments - there is a chance that they could be somewhere else. What we do to get round this is define another segment called Rest of World (ROW), which represents everywhere apart from the area we have covered with our original five segments. We now have six segments (A to E plus ROW) and can now say with absolute confidence that the missing person is somewhere in one of these, and so the POA's for segments A to E plus ROW must add up to 100% (ED: Not if you watch the X-Files, what about widening the search area to ROU - Rest of Universe?).

Here comes the second problem: how do you allocate the percentages to the segments? It is much better if a group of people (three is a good number) each have a go and average their results. Even then it's not as easy as it sounds. Experience has shown that there are all kinds of difficulties with this - asking a person to allocate POA's to six segments and at the same time make sure that they all add up to 100% is harder than it sounds - and we are looking for three people who can cope with it! An alternative method will be discussed shortly.

Let us suppose that we have found three people who are familiar with the incident history and the local area and can handle the percentages. Each of them, working on their own, decides what percentage likelihood they think there is of the missing person being in each of the segments A to E and ROW. They then pool their results and calculate the average for each segment - assume that this is what they end up with:

- segment A 17%
- segment B 24%
- segment C 21%
- segment D 18%
- segment E 19%
- ROW 7%

These then are our segment POA's arrived at by consensus. They tell us that our group of three considered segment B to be the most likely to contain the missing person with a 24% chance, followed by segment C with 21% and so on. They felt that there was a 7% chance (POA of ROW) that the missing person was not in the part of the map that gave us our search area for the Initial Plan.

And really that's about it. We have told you what POA's are and how you can arrive at them. However, there are a number of questions which we haven't really answered which we will look at now.

Why do you do it? as a Search Manager you need to sort out which of the segments you will search next as soon as your searchers start to arrive, which segments you will search next and which you will leave until last. The segments with the highest POA's are the ones which are thought to be most likely to contain the missing person and you will obviously start by searching these. When additional search resources become available you will put these into the segments with the highest POA's which so far have not been searched, and so on. POA at this stage is just an indicator which tells you in which order to search the segments.

Would you always do it? Generally speaking there are unlikely to be enough experienced searchers available all at the same time at the start to enable a search group to be put into all of the segments, so some form of 'priority listing' of segments has to be done.

Are there any other ways of doing it which are easier to handle for those who are uncomfortable with numbers? Perhaps the most user friendly method is one which uses 'likelihood Descriptors'. Here, instead of trying to come up with percentages, the people taking part in the consensus use a range of descriptors which go from "highly likely to be in this segment" then "fairly likely to be in this segment" to "average" then "fairly unlikely to be in this segment" and eventually "very unlikely to be in this segment". Each of these has associated with it a number which can be thought of as a score for that segment. Table 1) shows a typical set of descriptors and their associated scores.

Table 1. Likelihood Descriptors and their scores

Highly Likely	9
Fairly Likely	7
Average	5
Fairly Unlikely	3
Highly Unlikely	1

The 'in between' values 2, 4, 6, and 8 can be used to allow the participants to give finer shades of meaning to their scores.

The process works like this: suppose the three people mentioned previously (Dave, Pete & Jim) use this method to determine segment priorities for the Initial Plan. Working on their own, each of them decides which likelihood descriptor is best suited to each segment and gives the segment the appropriate score. these are then collected together and totalled like this: (Table 2)

Table 2. Segment Scores for Each of the Participants

Segment	Dave	Pete	Jim	Total	(%)
A	5	3	4	12	(16%)
B	4	7	6	17	(23%)
C	7	7	8	22	(30%)
D	3	5	5	13	(18%)
E	2	3	1	6	( 8%)
ROW	2	1	1	4	( 5%)
TOTAL				74	(100%)

Clearly, overall, segment C is considered to be the most likely to contain the missing person followed by segment B, then D and so on. Thus we have a priority list of our segments telling us where search resources should be committed so that if we have only sufficient manpower to search two segments then these are put into segments C and B.

It is not difficult to see that these total scores could be turned into percentages to give POA's by scaling each of them by a factor of  $100/74$  or 1.35. these are the values shown in brackets in Table 2 and this task is easily accomplished using basic computer software.

## Part Two

Dave Perkins and Pete Roberts explore Shifting PoA and the Segment Ladder in part 2 of PoA.

In the previous article we introduced the idea of PoA; PoA is a number, usually expressed as a percentage, which tells you how likely it is that the missing person is in a particular segment. In this article we will look at the concept of Shifting PoA - what it means, why it happens, what it depends on and just in case you really want to know, how you work it out. And along the way we will look at an alternative, non-mathematical way of doing the same thing.

It has to be said at the outset that if you really want to get involved with the numbers then use a computer and suitable software. The software which we are most familiar with is called Casie3, which calculates Shifted PoA's and does a whole lot more besides. From now on in this article, anything which has numbers associated with PoA's has been calculated by Casie3. Please don't try to do this manually; the formulae are given at the end of this article but life's too short for such things.

At the end of the previous article we talked about a consensus technique which used likelihood descriptors to generate PoA's from a number of people's interpretation of the story. Our example had three people and a Search Area with five segments plus RoW (Rest of World). When we put that consensus into Casie3 it came up with the PoA values

in fig.1.

Fig.1. Initial PoA's for the five segment example

Segment	Initial PoA
A	17.02
B	22.86
C	31.41
D	17
E	7.14
RoW	4.57

Another way to look at these is to imagine the segments placed in order from 'most likely' down to 'least likely'. Our list would therefore read as C,B,A,D,E,RoW. Suppose that sufficient resources are available to search two segments; clearly we will search the two at the start of the list, C & B. Let's say we do that and nothing is found - what do we do next? Looking at our list provides us with a simple solution - we have dealt with the first two segments, so we move on to the next two, A & D.

In reality, Shifted PoA has a bit more to it than that, but in essence what it is telling you, now that you have done some searching, is which are the segments most likely to contain missing persons. Generally speaking, for the first few phases of the search this means that you will go and search the segments which were next most likely to contain the missing person on your original list. This idea of a list of segments in priority sequence, and taking your segments to search from the top of the list is exactly what the technique called Segment Ladder (Sector Ladder) does, and we will now look at that in a bit of detail.

Fig.2. Segment Ladder for the Initial Phase

C \*  
B \*  
A  
D  
E  
RoW

Fig.2. shows the Segment Ladder for the Initial Phase of the search. In it, the segments are written down in the order in which they came out of the consensus and are therefore in the same sequence as the list we looked at a moment ago. We have put \* by the top two segments because they are the ones we are going to put search resources into in the Initial Phase (any symbol would do).

Once we have searched these and found nothing, we can assume for now that there is not much chance that the missing person is in there and we have missed them; they are far more likely to be in one of the segments that we have not searched. And so we get our list of segments for Phase 2 by moving the two segments we have searched in the Initial Phase down to the bottom of the Ladder and moving all the others up (fig. 3).



Fig. 3. Segment Ladder for Phase 2

A  
D  
E  
RoW  
C  
B

We still only have sufficient resources to search two segments, and so now we will put them into A and D since they are now at the top of our Segment Ladder. And so on - the process repeats itself, so that to get the Segment Ladder for Phase 3 we will move segments A and D down to the bottom of the Ladder and all the others up. In our simple example we can see that we will have a problem soon because in Phase 3 we will be running out of segments and will have to expand our Search Area into RoW. There is much more to the segment Ladder than that, but that is essentially how it works.

Back to Shifting PoA. As we can see, the PoA's for Phase 2 will be different from the initial PoA's - they will have changed ("shifted ") to take account of the searching done in the Initial Phase. It is not too difficult to work out what will determine the new PoA for each segment in Phase 2 - there are three factors to take into account:

1. Whether or not the segment has just been searched. If the segment was searched then the PoA will go down (you have just searched it and found nothing, and so the chance that the missing person is still in there is less than it was); if the segment was not searched then the PoA will go up (you didn't find the missing person where you were just looking, and so they are now more likely to be where you haven't looked yet). This is exactly the same as what we saw with the Segment Ladder - a segment which has just been searched goes down, and all the rest go up.
2. How thoroughly the searching has been done. If it was done at a high PoD then there is not much chance that the person is still in the segment you have just searched, so its new PoA will be low and the new PoA's of the segments you did not search will be quite high. If the searching has been done at a low PoD then there is a good chance that you will have missed them and the person is still in there, and so that segment's new PoA will only go down by a relatively small amount, and the new PoA's of the segments you did not search will only increase by a small amount.
3. The PoA the segment has to start with.

It is interesting to look at our simple example when we take it through a couple of Operational Phases using both Casie3 (fig. 3) and the Segment Ladder (fig. 4), and compare the two. We will assume that the searching gives us a PoD of 90%.

Fig.4. PoA's using Casie3

Segment	Initial Phase	Phase Two	Phase Three
A	17.02	33.27 *	8.29
B	22.86 *	4.47	11.13
C	31.41 *	6.14	15.29
D	17	33.23 *	8.28
E	7.14	13.96	34.76
RoW	4.57	8.93	22.25

Fig. 5. Segment Ladders

Initial Phase	Phase Two	Phase Three
C *	A *	E
B *	D *	RoW
A	E	C
D	RoW	B
E	C	A
RoW	B	D

In fact if you look at fig.4 and work out what sequence the PoA's put the segments in at each phase then you will see that the two sets of results are identical. That does not always happen, but they are always similar.

By now you might be thinking that it all seems an awful lot of fuss and bother, so is it worth it? The answer is not only is it worth it, it is absolutely essential. You must have some way of determining the segment priorities after each phase of the search. How else can you decide where to go and search next? You have two alternatives: invest in a PC and get a copy of Casie3 (a blank 3.5" disc plus SAE will eventually get you a copy from us, address at the end of the article), or get a copy of the Segment Ladder book (see bibliography). To start with we would recommend the latter. Casie3 is certainly not suitable for anyone who does not fully understand the concepts involved in search probabilities.

Formulae for Shifting PoA:

For a segment which has just been searched:

$$PoA_{new}(a) = \frac{PoA_{old}(a) \times (1 - PoD_{cum}(a))}{[PoA_{old}(a) \times (1 - PoD_{cum}(a))] + (1 - PoA_{old}(a))}$$

For a segment which has not been searched:

$$PoA_{new}(b) = PoA_{old}(b) \times \frac{(1 - PoA_{new}(a))}{(1 - PoA_{old}(a))}$$

where  $0 < PoA < 1$  and  $0 < PoD < 1$

segment (a) is the segment searched in most recent phase

segment (b) has not been searched in the most recent phase

PoA<sub>new</sub> is the Shifted PoA following the most recent phase

PoA<sub>old</sub> is the PoA prior to the most recent phase

PoA<sub>cum</sub> is the cumulative PoD for all the search resources which have been through the segment.

You can check that you are doing the calculations correctly with this example: the initial PoA of segment 1 is 26.92% (0.2692) and of segment 2 is 23.08% (0.2308). The segment is searched at 75% PoD (0.75). The new PoA of segment 1 should work out as 8.43% and of segment 2 as 28.92%.

# **Bibliography**

Search is an emergency, Lavalla, Stoffell and Jones, ERI, 1995

The Sector Ladder (Segment Ladder), Perkins and Roberts, 1994