Urban Search and Rescue

- An evaluation of technical search equipment and methods

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Abstract
This report evaluates USAR (urban search and rescue) search methods and technical equipment that are in use today by international USAR teams. In addition, improvements to both the search equipment and methods and to USAR in general are considered.

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Summary

Since Sweden first participated in an international USAR (urban search and rescue) operation in Armenia in 1988, Swedish USAR methods and USAR equipment have been modernised. From a disorganised, unprepared and unscheduled team SRSA (Swedish Rescue Services Agency) have a prepared and organised quick reaction task force today, with modern USAR equipment and trained personnel.

The purpose of this report is, in collaboration with the SRSA, to identify USAR search methods and equipment that are in use today on international USAR teams. In addition, improvements to both the search equipment and methods and to USAR in general are considered.

As the research to this report shows, there is defective documentation, not only at the SRSA but also at several other international organisations. A questionnaire was used to collate specific information from earlier operations.

The requested and analysed information concerns factors regarding the different organisations' earlier USAR operations. Above all information was sought about search methods and search equipment, how these have functioned during operations and whether or not they have contributed to lifesaving.

This report presents how different USAR methods and equipment work. The presentation concludes with a summary of the specific advantages and disadvantages of various methods and equipment.

The research also shows inferior documentation and spreading of information between the organisations as regards the specific rescue scenarios that have occurred. Inferior documentation leads to difficulties when evaluating methods and current search equipment.

To be able to conduct an analysis of different search methods and equipment efficiency in the future, a suggestion of how a standardised reporting model and the components it should contain are specified.

Sammanfattning (Summary in Swedish)

Från det att Räddningsverket för första gången deltog i en internationell urban sök- och räddningsinsats i Armenien 1988 har verket en strävan att förbättras. Från att 1988 varit en dåligt förberedd organisation har Räddningsverkets sök- och räddningsstyrka utvecklats till att idag vara en tränad snabbinsatsstyrka med modern sök- och räddningsutrustning.

Syftet med detta examensarbete är att i samarbete med Räddningsverket kartlägga de urbana sök- och räddningsmetoder och utrustningar som används idag av internationella team. Även förbättringar gällande dels sökutrustningen och metoder och dels USAR rent generellt är taget i beaktning.

Då studien visar på mycket bristfällig rapportering och dokumentation bland inte enbart Räddningsverket utan flertalet andra internationellt verksamma organisationer genomförs informationshämtning i form av ett frågeformulär.

Den typ av information som har efterfrågats och studerats är faktorer rörande de olika organisationernas tidigare insatser. Framförallt gällande hur användandet av metoder och utrustning har fungerat i skarpa lägen och om de i så fall har lett till räddning av någon drabbad.

I arbetet görs en genomgång på de sök- och räddningsutrustning och metoder som används bland de undersökta organisationerna. Dessa utrustningar och metoder kompletteras med en sammanställning över de för och nackdelar som kommit upp under arbetets gång.

Stora brister har även påvisats gällande organisationernas dokumentation samt spridning av information om de specifika räddningsscenariers som förekommit. Detta leder till stora svårigheter då de metoder och tekniska utrustningar som används skall utvärderas.

För att i framtiden kunna göra en korrekt analys av de olika metoderna och utrustningarnas effektivitet ges därför förslag på en tankemodell för rapportering och dokumentation samt de komponenter som där bör ingå.

Foreword - Acknowledgements

To obtain a Master of Science in Risk Management and Safety Engineering at Lund University, graduate students must write a thesis based on a final project. The efforts correspond to full-time studies for one semester, i.e. 30 ETCS credits or 20 Swedish credits.

Many people have been of great help to us while working on this report, in particular, James Butler, Swedish Rescue Services Agency, who helped us with the formal translation of the questionnaire, and those who have taken the time and effort to answer it.

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Carl-Johan Bäckström & Niclas Christoffersson

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1. Terminology

1.1 Acronyms & Abbreviations

FOI	Totalförsvarets forskningsinstitut, Swedish Defence Research Agency
INSARAG	International Search and Rescue Advisory Group
LEMA	Local Emergency Management Agency
OCHA	Office for Coordination of Humanitarian Affairs
SAR	Search and Rescue
SSD	Sound or seismic detector
SRSA	Swedish Rescue Services Agency
UNDAC	United Nation Disaster Assessment and Coordination
USAR	Urban Search and Rescue

1.2 Glossary

Canine	A search dog that is specialised in searching for humans in *rubble.*
Detection	Indication that there is a victim located in the *rubble*.
Localisation	The pinpointing of a victim's location in *rubble*.
Object	A specific search area or collapsed structure in a region affected by a disaster.
Rubble	What remains after a collapsed construction.
Site	See *object*.
Technical search equipment	All modern technology used in the search and rescue operation. This does not include equipment used to bring the victim out from the *rubble,* such as drilling machines, welding sets, etc.
Urban Search and Rescue	The search for and rescue of trapped victims in urban terrain.
Victim	A live victim buried or trapped in rubble.

2. Introduction

Since 1988 the SRSA has, on commission from the Swedish Government, had the task of maintaining an emergency preparedness organisation for overseas disaster and humanitarian aid operations. This emergency preparedness organisation consists of personnel and materiel, which can at short notice be sent to wherever they and it is required. The operations are varied and so, as the years have gone by, the SRSA has developed its activities so that we can take on a whole range of miscellaneous tasks. (Räddningsverket, 2005)

2.1 Background

Since Sweden first participated in an international USAR (urban search and rescue) operation in Armenia in 1988, Swedish USAR methods and USAR equipment have been modernised. From a disorganised, unprepared and unscheduled team SRSA (Swedish Rescue Services Agency) have a ready, organised quick reaction task force today, with modern USAR equipment and trained personnel.

There are currently several different types of USAR methods and equipment, most of them used in some way by international USAR organisations. The methods and the equipment are in some cases unique for searching for victims in collapsed structures and rubble.

Up to now, the SRSA has never investigated whether if, or which of the existing and used USAR methods or equipment that really work under real conditions. Despite this, great efforts are invested to improve methods and equipment without any real knowledge about their efficiency.

This project was commissioned by the SRSA. The SRSA conducted this study to obtain clarity in their USAR work, and by this means, make their USAR operations more effective in the future.

This study evaluates existing USAR search methods and equipment in terms of efficiency, in the search for survivals in rubble and debris after collapsed structures under real conditions.

2.2 Objectives

The purpose of this report is to provide a general description of the search methods and the search equipment used in the field of USAR today. Additional purposes are to investigate the efficiency of current methods and equipment in detecting and locating live victims under real conditions in collapsed structures and rubble and to give suggestions on improvements for the existing methods and equipment. We hope to achieve this by evaluating the existing methods and equipment and by examining some of the research projects on future equipment that are in progress at the time of this study.

We hope that this report will be useful as basis in research on the issue.

This kind of study has been requested by both Swedish and several other international USAR teams. We, therefore, hope that by writing this report in English that even the international USAR teams will be able to use the results of the study in their research and future development.

2.3 Tasks

The following tasks will be undertaken to achieve the objectives:

- Identify methods used to detect and locate victims in rubble.
- Identify equipment used to detect and locate victims in rubble.
- Identify the methods and equipment that is most commonly used.
- Review the related advantages and disadvantages to the type of methods and equipment.
- Identify whether or not there are currently any alternative methods or equipment used in other fields of activities that can be useful for USAR.
- Give suggestions for improvement of existing USAR methods and equipment so that the search for live victims becomes more effective.
- Identify the distribution over time of rescued victims related to the different methods and equipment used by the investigated teams.

2.4 Scope

A study of any complex model of the distribution of live victims in or under rubble after a disaster is beyond the scope of this report. We, therefore, assume a homogenously spread of victims throughout or in the rubble.

The period of missions investigated stretches from 1988 to 2005. The selection of investigated USAR teams was preliminarily based on reports from the INSARAG (International Search and Rescue Advisory Group).

No consideration will be given to any cultural or political factors that might affect the use of any USAR methods or equipment.

2.5 Target group

This report targets personnel and organisations with experience of USAR operation or others with interest in this issue.

To fully understand this report, some background knowledge of statistical analysis, and the method of procedure in international USAR operations is required.

3. Method and structure of the report

This chapter describes the method used to fulfil the objectives of this report.

3.1 Method

3.1.1 Literature study

Reports from SRSA's earlier international USAR operations gave the authors a basic USAR knowledge. Nevertheless, because of deficient documentation of previous operations in the matter of the USAR teams' used methods and equipment and their efficiency, information also had to be gathered from other international USAR organisations and teams.

The primarily gathered literature was, due to the lack of equipment-specific information, only used to study the basics of the methods that different teams have implemented in previous operations.

To better understand the objective of this report and the contents of the literature, the authors participated in an early stage as observers in an USAR exercise for the Swedish USAR team arranged by the SRSA in May, 2005.

The research and the literature study of different organisations USAR methods and equipment continued throughout the entire period the authors worked on the report.

3.1.2 The lack of documentation

As mentioned above, documentation from earlier USAR operations between Sweden and several other organisations is deficient in the area of the used methods and equipment and their efficiency. This means that the data required for this report had to be obtained in some other way. Therefore, the information essential for this report is based on observations, a questionnaire (See Heading *3.1.5 The Questionnaire)* and interviews with people who have participated in earlier USAR operations.

3.1.3 Observations

To obtain better knowledge and experience of how the methods and the equipment are used in the field of action, the authors participated in two USAR training exercises.

The first exercise took place during May, 2005, and was located in Skövde, Sweden. It was a basic USAR exercise intended for the SRSA's international USAR team. The team trained on how to use the technical equipment, how to mark a searched site and how to search with dogs.

The second exercise (Eurosot 2005) was a full-scale tabletop community exercise on seismic risk. Eurosot 2005 was located on the Italian island Sicily. USAR teams from five different countries (France, Greece, Portugal, Sweden and the

United Kingdom) actively participated during this exercise. The teams trained, for example, on how to enhance effectiveness in responding to a major disaster, co-ordination, communication between teams, and increased cooperation between EU Member States.

Along with observations from these two exercises, the authors also investigated how to improve the equipment and methods used by USAR.

3.1.4 Selection of respondents

The work of selecting the respondents, handing out the questionnaires, and receiving them was divided into three different steps as illustrated in Figure3.1.

First, an inquiry of assistants was sent by email to the different contacts named on the INSARAGs' homepage (OCHA, 2005), and at the Relief web site (ReliefWeb, 2005). If there was no contact specified, the inquiry was sent by email to the contact addresses on the organisations homepages.

A total of 28 of 56 contacted organisations answered positively to the query to assist in this research. Questionnaires were sent out to those 28. Thirteen completed questionnaires were returned and those from 13 different organisations. In a comparison of the number of organisations that the questionnaire was sent to, this gave the investigation an answer frequency of 13/28 (46.4 %).

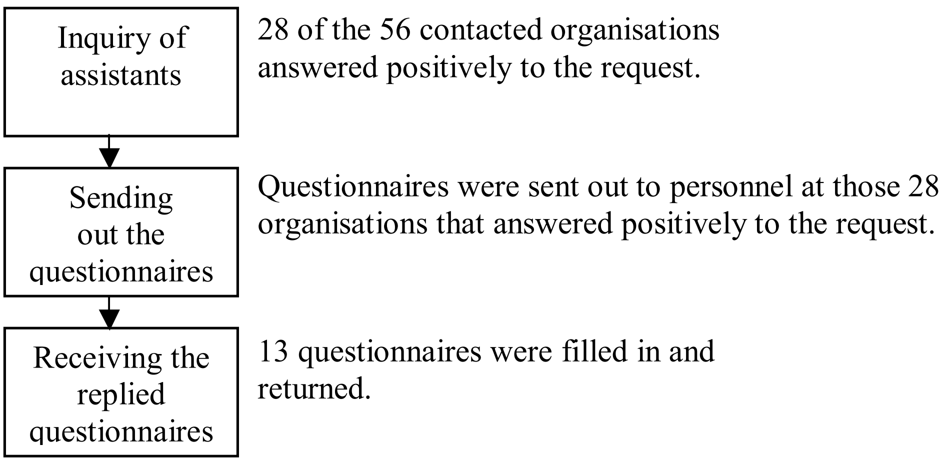

Figure 3-1 *Illustration of the procedure of sending and receiving the filled in questionnaires*

Factors that might have affected the respondents are the number of great natural hazards (a hurricane in the USA; a mudslide in Mexico; an earthquake in Pakistan) that occurred during the response time of the questionnaire and shortly after (AUG – SEP 2005).

A larger number of respondents would probably have resulted in an analysis of more types of methods and equipment. More respondents would also have given more data to the statistic analysis and therefore have given a more correct analysis.

3.1.5 The Questionnaire

3.1.5.1 Why a questionnaire

The majority of the information and data needed for this report was in most cases spread within the contacted organisations. This meant that to gather the information and data needed from every involved organisation would have resulted in several interviews within the same organisation. With 28 organisations to analyse, this would have taken too long to be able to conduct within the time limit for this report.

With factors such as the number of personnel to be questioned, the dissemination of information inside each organisation and personal knowledge about the time the respondent spends in their office, the method selected for the collection of information was a questionnaire.

3.1.5.2 Advantages of a questionnaire

There are both several advantages and disadvantages of gathering information through a questionnaire. The two major advantages that lead up to the decision to use a questionnaire was first that the respondent would be able to answer the questions in their own time. With background knowledge of how little time the people involved in international USAR operations spend in their offices, the questionnaire was assumed to be the best way of gathering information related to a normal interview.

The other major factor was the dissemination of information within the different investigated organisations. The possibility that the respondents would be able to answer all the questions alone was assumed to be very low. Therefore, a questionnaire that could be forwarded inside each organisation was assumed to lead to a higher answer frequency on the questions.

Ejvegård (2003) summaries other advantages and disadvantages with a normal interview related to a questionnaire. These factors are presented in two lists. Below is a free translation of these two lists.

Advantages of a questionnaire in contrast to a normal verbal interview

- Any impact from the interviewer is avoided.
- A great number of respondents can participate which makes it easier to stratify and to statistically analyse the responses.
- Persons spread around several locations can be contacted easier.
- The respondent can carefully think through the answers at their own pace.
- It is easier to analyse the responses.
- Despite a greater number of interviewees, the analysis can be done much quicker.
- All respondents get exactly the same questions.

- All respondent are questioned at approximately the same time.
- It is easier to make an analysis of the drop out.

Disadvantages of a questionnaire in contrast to a normal verbal interview

- The responses are not as full and complete as in a normal interview.
- There is no possibility for the scientist to immediately clear up misunderstandings.
- There is less possibility for the scientist to supplement the questionnaire with questions.
- Internal impact of the respondents can affect the responses.
- There is less room for openness.
- Generally, a shorter preparation time for the scientist.

3.1.5.3 Formulating the questions

Together with representatives involved in USAR from the SRSA, the specific information required was specified. From that, the different questions were formulated and summarised as a questionnaire that was used.

Great effort was invested in formulating the questions so that the respondents would not misunderstand them. If this was to be the case, the validity of each question and the reliability of each response would have been reduced (*see Headings 3.1.8 Reliability and 3.1.9 Validity control*).

The questions were also constructed so that the respondent could answer them as quickly and easily as possible. Unfortunately, this was impossible in some parts of the questionnaire because of the need for open questions.

Before sending out the questionnaire, the formal translator at the SRSA read it through and corrected the English language where necessary.

3.1.5.4 The structure of the questionnaire

The questionnaire (*Appendix 1*) is divided into two sections. The first section contains four general questions about the organisations' methods and equipment that are used in their USAR operations.

The second part contains thirteen questions about the USAR operations and situations that the respondent or his/her organisation has experience of.

3.1.5.5 The distribution of the questionnaire

Respondents could choose to receive and reply to the questionnaire in three different ways. The first option was to receive it as a PDF document by e-mail, print it out, fill it in, and return it by ordinary mail. The second option was to receive it electronically by e-mail, fill it in, and return it by e-mail. Last option was to receive it by regular mail, fill it in, and send it back to us in the same way.

This multiple choice receiving and returning method was done so that the respondent could find the way that suited him/her best and therefore increase the number of questionnaires responded to.

The electronic version required special software. Event though this software was a free download version, this might have affected the use of it and the number of returned responses.

The response time to the questionnaire was primarily set at approximately five weeks. A reminder was sent out two weeks afterwards to the contacts at the organisations who had first received the questionnaire.

3.1.6 Qualitative analysis

The method of procedure has not been separated into different specific phases. For example, the literature study was underway during the entire work. The formulation of the task has more or less been changed from the beginning of the study to after the collection of data. The gathered information has been analysed throughout the entire process which itself has influenced the task and the hypothesis of this report. This means that work on this report contains characteristics of a typical qualitative analysis, according to Carlsson (1991).

3.1.7 Method of analysis

Primarily all the answers to the questionnaire were summarised in two separate documents. The first document summarised data, the statistics and the information from the different organisations' earlier operations. The other document summarised the answers from all the open questions. The questionnaire was summarised without any way to identify the participating organisations other than a reference number. This was done so that the authors could maintain objectivity (See *Heading 3.1.10 Objectivity*)

The second stage of the analysis was to revise the summarisations. This was done by continuously revising the method- and equipment-specific information, and by separating data into tables and statistical parameters.

3.1.8 Reliability

When responding to this type of questionnaire, the factor of prestige is assumed to be the biggest source of error of reliability (Ejvegård, 2003), since teams might want to look more effective then they really are. The authors used two different methods to avoid this as far as possible and to try to keep reliability as high as possible in the report.

The first method was to use control questions. If a summary of the responses to questions 10,11,12 and 13 (see the questionnaire *Appendix 1*) are all the same, the reliability of the answers are assumed sufficient. Ejvegård (2003) calls this method of reliability test for *Control questions*. The answers were also controlled as far as possible with available reports from the investigated organisations.

The second was, in an early stage, to inform all respondents that the questionnaire "*will not be published with any reference to you, your organisation or your USAR team, but rather with a reference number*" (The questionnaire*, Appendix 1*). This statement was assumed to help reduce the factor of prestige among respondents.

3.1.9 Validity

A great risk when conducting a normal verbal interview is that the persons directly involved in the interview influence and affect each other. This could result in that the questions and the answers become defective, with a distorted result as an outcome. One way to avoid this is to base the interviews on a questionnaire. Then the respondents get the exact same question asked in the exact same way. This means that the persons involved are unable to directly affect each other and the result is more correct. (Ejvegård, 2003)

Some organisations sent reports from different operations that they had participated in. The validity was as far as possible verified by comparing the responses from the questionnaire with information in the reports. If responses corresponded to the reports, the validity of the questionnaire could be assumed high. Ejvegård (2003) describes this method more closely in his book about scientific methods.

3.1.10 Objectivity

As mentioned under heading *3.1.5 The Questionnaire*, one major risk when conducting a normal interview is that the persons directly involved in the interview influence and affect each other. One way to avoid this is to base the interviews on a questionnaire. Then the respondents get the exact same question asked in the exact same way. Using a questionnaire is, therefore, a way to maintain objectivity among the authors. (Ejvegård, 2003)

In the analysis, all information that could connect the answers in the questionnaires to any country or organisation was removed or concealed. Instead, the responses were identified with a reference number only. To maintain objectivity the reference letter or number was the only connection to the responses used during the first analysis.

The contacts and the names of the organisations were only used in a second stage if the answers in the questionnaires had to be supplemented or explained by the respondents. After the first analysis, the answers were controlled with reports as described under the heading *3.1.8 Reliability* and *3.1.9 Validity*.

3.2 Structure of the report

This report is divided into five parts.

- The first part consists of Chapters 1, 2 and 3. Chapter 1 is a description of the terminology. The introduction chapter (Chapter 2) contains information of the background of this report along with a short description of the task. The third chapter consists of a description of the methods used to conduct this research.

- The second part, Chapters 4 and 5, describe the different equipment and methods that the investigated teams and organisations use in their USAR operations. Here is also a presentation of method- and equipment-specific advantages and disadvantages that the analysis resulted in.

- The third part, Chapter 6, consists of a quantitative analysis of data collected with the questionnaire.

- The fourth part, Chapter 7, summarises the comments and the reflections of the teams on how the USAR operations could become more efficient. Data presented in this chapter comes from responses to the questionnaire or from observations.

- The fifth part, Chapters 8 to 10, consists of an analysis of the system of reporting and the conclusion together with a general discussion of both of these and the report.

4. Search Equipment

This chapter contains a description of the equipment that the investigated teams use in their USAR work. Under Chapter *6. Quantitative analysis of responses to the questionnaire*, there is information on how many of the investigated teams that have used the equipment analysed in this chapter.

Unless otherwise stated, the information in this chapter comes from the authors' observations and the respondents' answers to the questionnaire.

4.1 Detection and localisation

The use of the USAR equipment is divided into groups depending on its field of application. A number of the available USAR equipment is only used for detection of a trapped victim. Some USAR equipment is specialised for locating where inside the rubble a trapped victim is located; in such a case, detection with other equipment is essential. There are a few types of special equipment that can combine both the detection and localisation of a trapped victim.

Unfortunately, the designation itself does not explain what the equipment is aimed for. As an example, equipment used for localisation as a rod-based camera, goes under the name Electric visual detection device.

4.2 Electric visual detecting device

Electric visual detecting device (Search camera) is a video camera, modified to search for and pinpoint the location of victims trapped in void spaces. For the rescuers to be able to reach in to a void space, the camera is mounted on a telescopic rod or on the top of a bendable cable. Information from the camera can then be viewed by the operator on a video screen mounted at the other end of the rod.

When searching the void space, the operator can sweep through it by moving the head of the rod where the camera is mounted. The light in a void space can be limited; therefore the head of the rod normally provides a light source.

In addition to the camera, the rod is often equipped with an acoustical system. This system enables acoustical search and the ability for the operator to communicate directly with a trapped victim by voice. The acoustical system makes it also possible for the operator to listen for sounds in the rubble through a pair of headphones.

Some manufactures use a combination of the normal video camera with an infrared camera (*See heading 4.4 Thermal imaging detector, Infrared camera*) to search for and locate a victim.

4.2.1 Analysis of electric visual detecting device

Before using a search camera, other equipment or methods have normally been used by the teams in the study to detect and pinpoint the location of a victim. The search camera is then used to visually locate a victim and collect information about the spaces in the rubble.

Among the teams, the normal way of operating a search camera is that one operator manually handles the camera, another operator watches the screen and listens for sounds from the microphone, communicating with the victim if possible, and helps the other operator to navigate the rod.

Some operators say that it is easier to interpret the image on a colour video screen and some say it is easier on black and white. A discussion of this is beyond the scope of this study, which does not analyse different types of video screens.

During the observations and from the analysis of the questionnaire, several advantages, and disadvantages of the Visual detecting device were identified. A summarised list of them follows below.

Advantages:

- Through the search camera it is possible for the rescuers to decide the condition and position of a trapped victim. This information together with information from the interior of the rubble can help rescuers to decide on how to enter the rubble and rescue the victim.
- With direct communication such as the search camera, rescuers are able to encourage the victim to cooperate and help them stay alive.
- A video screen allows several rescuers to simultaneously view and interpret the picture and the situation.

Disadvantages:

- The search camera needs holes or openings to be able to access a void. Without the right tool, it is difficult to find or make access to a void space for the camera.
- The camera is expensive.
- To search through a site with a search camera, without any other USAR detection or localisation equipment, is in many cases impossible. A possible location of where a victim is trapped is needed in order for the search camera to fulfil its major purpose.
- In contrast to a search camera mounted on a bendable cable, the one mounted on a telescopic rod needs a straight line to be able to access rubble.
- A search camera has a limited range of how far it can reach into rubble.

- The search camera has limited working hours due to limited battery life.

4.3 Fibre optic detector

Fibre optic is an optical system in which a ray of light is lead through a light pervious flexible cylinder with the approximate size of a human hair (5 – 70 μm). This specially made fibre optical cylinder is of glass or a polymeric material. (Nationalencyklopedin, 2005)

The transferred light is totally reflected within the core of the cylinder and lead through it under repeated reflection against the cylinder surface. To protect the fragile cylinder from damage, a plastic layer or a cable sheath normally covers the cylinder. (Nationalencyklopedin, 2005)

When fibre optic is used for the direct transfer of a picture, as in a fibre optic camera, a cluster of arranged optical fibres must be used to accomplish a direct transfer. The cluster of fibres is in one end provided with a small lens and a viewing ocular or video screen in the other. To get a better view in darkness, the optical camera is often provided with a light source. (Nationalencyklopedin, 2005)

Observations show that, during USAR operations, a fibre optic camera helps rescuers to visually search for and pinpoint the location of a victim inside rubble. To be able to reach further into a void space, the optical camera is usually mounted on a telescopic rod. Rescuers then try, as with the search camera, to access the void with the fibre optic camera through holes and openings in the rubble. Information on the interior of the rubble can then be viewed by the operator on the video screen. In most models of fibre optical detectors, the operator is also able to sweep the voids with the camera by turning the head of the camera in desired directions.

4.3.1 Analysis of fibre optic detector

For the teams, the fibre optic detectors worked as a complement to a regular search camera. (See heading *4.2 Electric visual detecting device*, for more information about the search camera*)*. The following advantages and disadvantages of the fibre optical detection equipment were identified based on observations and the questionnaire.

Advantages:

- The size and diameter of a fibre optic search cam is small, in relation to other visual rod-based detection or localisation video systems. This makes the fibre optic system capable of accessing smaller voids and openings.

- The smaller detection system contributes to a reduced package volume in comparison to other rod-based video systems.

- Because the system almost exclusively relies on optic transfer, the fibre optic system itself is insensitive to interference from surroundings such as magnetic fields.

- The equipment is inexpensive in contrast to an ordinary search camera.

Disadvantages:

- The systems have, as all other rod-based detection or localisation systems, a limitation on how far it can reach into a void.
- As the operator has no reference points for size, location, or distance on the two-dimensional video screen, it can be hard for them to orientate inside a void.
- If the optical cable breaks or is damaged, repairs or joins have to be carried out under very clean conditions and with very high precision.

Makita (2004) summarised a list in the report *Development of compound eye camera system for searching in rubble* disadvantages of both the fibre optic camera and the ordinary search camera. A section of that list follows below.

- Heavy weight means that fire fighters cannot operate it for a long period.
- Visibility is so narrow that the human eye cannot see the situation correctly.
- Operators cannot know which gap the camera has been inserted through. Therefore, thorough investigation of possible gaps is difficult.
- Only image and sound data are obtained. High skilled intuition of human is necessary.
- Operational distance is too short to apply them to underground shopping arcades and large structures.
- Only the head of the equipment moves, and it cannot go into rubble piles actively.
- The equipment can measure one point and only temporal information is collected. Therefore, fire fighters cannot easily know the global situation.
- The information collected cannot be integrated with the other equipment such as robots and PDA.

4.4 Thermal imaging detector, Infrared camera

All objects with a temperature over absolute zero (-273.15°C) transmit thermal energy, infrared radiation. The higher the object’s temperature is, the more radiation it transmits. The transmitted infrared wavelength is not visible to a naked human eye. Instead, an infrared camera has a detector that reacts to the infrared radiation from the surrounding. The detector together with the electronics in the camera then translates the infrared light into signals that are visible to humans, for example, into a picture on a video screen. (Corbin, 2000)

By using the thermal energy technique together with a thermal image camera, it is possible to measure temperature and to show a picture of the thermal energy from an object on a video screen. Either the mapping shown on the video screen is in grey tones or some form of pseudo colours. One colour can represent, for example, a certain temperature range on the object. (Corbin, 2000)

4.4.1 Analysis of Thermal imaging detector, Infrared camera

The thermal imaging detector was used by the respondents to search voids and openings in the rubble.

Based on observations and the questionnaire, the following advantages and disadvantages of the thermal imaging detector were identified.

Advantages:

- The thermal imaging detector can be used as command equipment. Set up at a short distance from the site, the on site commander can monitor the situation of, and around a site, even in darkness or limited visibility.

- Rescuers can detect a victim who is not visible to the human eye, for example, through smoke or in total darkness.

- A dust covered victim trapped in a void, not able to make any movement or sound, can be hard to detect or locate with normal visual detecting equipment. Using thermal imaging detectors, the victim's body heat is all that is needed for detection or localisation.

- The mapping from a thermal imaging detector can in some cases be digitally saved and therefore be useful as support for a report or documentation.

Disadvantages:

- It can be difficult for the operator to interpret the mapping on the screen. If the temperature of the surroundings is close to the victim's temperature, interpretation becomes even harder.

- The infrared camera senses reflected infrared radiation, which can contribute to distorting the mapping. For example, a cold-water puddle can reflect radiation and appear as a hot spot on the video screen.

- The thermal imaging camera has a limited visual range.

4.5 Canine

What we call smell is gas consisting of molecules or particles which is transported through the air. The particles in the air hit receptors in the nasal cavity that transform the gas to a nervous signal. The receptors send the information to the brain, which interprets them and transforms them to impressions (Räddningsverket, 1997). Therefore, logically it is the number of receptors that determine the sensitivity in the sense of smell.

A dog normally has around 200 million receptors. This is 20 to 40 times more receptors than a human being has. The dog's superior sense of smell makes it possible for the animal to detect far more complex and much weaker smells than humans can (Swedish Rescue Services Agency, 1997).

The task for the canines is to find humans buried in rubble, or trapped inside blocked spaces. (Räddningsverket, 1989). By using its superior sense of smell, the canine can detect the smell of a victim and thereby find the area or location where the victim is trapped. To do so and not mix up the smell with something else, the canine trains to find a victim through the total model of fragrance from humans (Räddningsverket, 1997).

When the canine has found a victim, it marks the finding for its handler. There are several different types of methods for the canine to mark a victim depending on the nature of the dog. (Jäverud 2002) The methods of marking will not be further analysed in the report because the different types of methods are assumed not to affect the efficiency in the search for victims.

There are several different types of dogs used in USAR operations. Some of the dogs are only trained to detect living victims, others to detect both living and deceased. (Swedish Rescue Services Agency, 1997)

There are also several different basic techniques for searching rubble with a canine. There will be no further analysis in the report because the different types of techniques are assumed not to affect efficiency in the search for victims.

4.5.1 Analysis of the canine

The analysis of the questionnaire clearly shows that the canine is currently one of the most frequently used types of equipment for detection of victims trapped inside rubble.

The study revealed several advantages and disadvantages of the canine. The following reflections come from observations and the questionnaire, followed by comments from different literature sources and reports on the topic of canines.

Advantages:

- The analysis of the questionnaire clearly shows that the most commented and, among the respondents, appreciated advantages of the canine are the time it takes for the dog to search through an area or site.

- According to the respondents, the canine is currently the most effective type of equipment used to detect trapped victims in rubble. The canine's mobility combined with is ability to detect hidden live victims makes it a valued asset.

- Canines are able to detect and locate victim both conscious and un-conscious.

Disadvantages:

Responses and observations primarily resulted in the following disadvantages of the canine as a type of equipment.

- If the dog handler and the dog are not correctly trained together, the handler may have problems interpreting the signals from the dog. This is something that could also happen if the canine encounters situations in which it is disturbed or feels discomfort. Other interpretation problems occur when the dog is unable to determine if the detected victim is alive or dead.

- The canine demands continuous care to work properly. The amount of care needed is, in many cases, directly related to the climate and the type of rubble in the disaster area. This means that the time the dog can be used as equipment is reduced and that rescue workers must spend time caring for the dog instead of participating in the search.

- The canine has limited working time. A search entails, in many cases, hard work for the dog with possible exhaustion as a result. If the dog is not able to rest, it will not work properly and this may, in the end, affect the result of the search.

- Under windy conditions, the smell of a buried victim can reach the surface of the rubble in a completely different area than the one where the victim is trapped. This means that the canine can mark an incorrect victim location.

- If the canine is not trained properly, it can feel discomfort and be confused when it encounters scents on the site that it is not accustomed to.

- If the temperature in the rubble is too high, the canines cannot function in it, or even enter it.

The FOI (Swedish Defence Research Agency) compares the canine to gas sensor in a science project (Jubrink, 1998). In addition to the above-mentioned advantages and disadvantages, FOI also mentions the following factors in their report. (The text is a free translation into English)

Advantages:

- High accuracy of aim.
- Well tried and tested method of working.
- Possible to use for tactical purposes.

Disadvantages:

- High costs in training each canine.
- Limited operational lifetime.
- Difficulty in climates with high temperature and high humidity.
- The canine has a cost even when they are at rest or on stand by.
- The canine can hit strong gases or liquids that can damage the sense of smell.
- The canine can be unfocussed and not willing to search.

4.6 Sound or seismic detector

The SSD (Sound or Seismic Detector) systems work as an amplifier of seismic activity. Such a system consists of a number of special sensors that are able to pick up vibrations and sounds that are not detectable by humans. These sensors connect by cable to an amplifier with special indicators.

The rescue personnel place the sensors in the rubble. Operators can, by reading the sensors and by listening in their earphone determine the occurrence of sound and seismic activity around the sensors.

To be able to detect a live victim there must be some kind of sound or movement that causes vibrations in the rubble. When a victim is doing any of the two mentioned activities, small vibrations occur. These vibrations transmit through the collapsed construction of the building. The sensors are then able to pick up these very small vibrations. The operator can, after amplification, listen for these sounds and vibrations through the earphones.

By moving and placing the sensors in a special pattern, operators can pinpoint the area that is in best acoustic or seismic connection to a victim.

4.6.1 Analysis of sound or seismic detector

Sound or seismic equipment is commonly used by the respondents. The equipment is used by the teams to both detect and locate buried live victims. The use of sound or seismic detectors in the phase of detection is primarily done when other methods of detection are missing, for example, a canine.

Advantages:

- The main advantage of the sound or seismic detector is the ability to pinpoint accurately a signalling trapped victim.

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Disadvantages:

- One main disadvantage is that if rescuers are to be able to detect or locate a trapped victim, they have to make some kind of noise or movement actively. This means that an unconscious victim remains undetected after a search.

- The sound or seismic detection equipment depends on how well the signals from a victim can transfer in the right direction through the rubble. This means that it is difficult to ascertain the location of a victim trapped under two or more layers of concrete.

- If the rubble is not homogenous, this will cause problems for the operator. Signals might not transfer to the same extent in all directions. This variation in signal transfer can provide a better indication in a completely different area than the one in which the victim is actually trapped.

- Other problems for the operator are interference of signals from other sources than the victim. If the search area is not completely silent, the sound or seismic equipment will indicate other sources of vibration than a victim. If the interfering signal is too strong, the operator could completely fail to detect or locate a victim.

- The equipment requires batteries, which gives it a limited time of use.

5. Search methods

This chapter contains a description of search methods that the respondents use in their USAR operations.

Unless otherwise stated, the information in this chapter comes from the authors' observations and the respondents' answers to the questionnaire.

5.1 Physical manual search

Manual search means all search methods and efforts used for detection or localisation of dead or alive victims that do not include any special search equipment. In this report, a manual search is divided into organised and unorganised search.

Unorganised physical manual search
An unorganised manual search is the type of search that is conducted on a site before any type of command is set up. This type is the one that civilian locals (family, neighbours, people who happen to be in the area) often use before rescue personnel arrive at the site. The unorganised manual search will not be further analysed in this report, due to the lack of data and information.

Organised physical manual search
The organised manual search is the type that the investigated USAR teams use. In general, it is conducted in the same way by all the USAR teams.

Rescuers normally conduct some kind of manual organised search before they apply any technical search equipment. Rescuers try to establish contact visually or vocally with victims by systematically searching a site. This type of search is conducted on foot, walking, or climbing, and at the same time shouting, sometimes with a megaphone. Lose and not too heavy pieces of debris are moved to increase chances of detecting or locating victims.

Another way of performing a physical search is to distribute rescuers throughout the rubble and by simultaneously signalling and listening to try to make contact with a trapped victim. The distribution of the rescuers can in this case be carried through in the same way as the placing of the sensors in a search with an SSD (See *5.3 Methods used with technical search equipment*).

When the manual search is underway it is preferable (as in many USAR search techniques) to have the rubble area undisturbed by other sound sources than sources from rescue personnel. Otherwise, rescuers on the surface of the rubble might not be able to hear a victim signalling for help.

Depending on the information given by locals and information about the collapsed structure, an organised search is not always included in the search of a site. If, for example, there are locals who say that they know that victims are buried in the debris, and that they have walked through the rubble shouting for them without any results, then a search of this site would probably not start with an organised manual search. Instead, to save time, the team leader would probably order the search to start with canines or with technical search equipment.

5.1.1 Analysis of manual search

As mentioned above, an organised manual search are used by almost every investigated USAR team in one form or other. In addition, this USAR method has, according to the analysis of the questionnaire not resulted in the greatest number of rescued survivals (See Chapter *6. Quantitative analysis of responses to the questionnaire* for more information). On other hand the *Unorganised Physical manual* search that takes place before any rescue team has arrived, can be assumed to generate the greatest number of rescued. This is because locals are assumed to find all the easily detected victims before any international USAR team is in place.

An analysis of the responses and of the observations generated several comments and reflections on the advantages and disadvantages of this type of search method. A summarised list of these follows below.

Advantages:

- According to the analysis of the responses, the greatest advantage of a manual search is the short time it takes to search an area.

- This search can be conducted without any need for technical equipment.

- A victim has a good chance of being detected at an early stage of a rescue operation if the victim is able to send a signal strong enough to be picked up by rescue personal.

Disadvantages:

- This type of search needs great number of rescue personnel to search larger areas with rubble. In rougher rubble, this method becomes time-consuming.

- If the area is not sufficiently isolated from other sources of disturbing signals, rescue personnel can easily find it difficult to discern signals from a victim.

- This method largely depends on human senses. A rescuer can easily miss a weak signal from a trapped victim because of all other sense impressions.

- Even if a victim is able to send a signal, it might not be strong enough for humans to detect on the surface.

- It is hard to detect a victim trapped under several layers of debris.

- "*This operation is more exacting than the others and poses a significant risk to the personnel involved in the operation.*" (FEMA, 2003)

5.2 Methods used with canine search

Training
Today there are several different canine schools around the world, each school with their own training and methods. This means that canine search methods differ from team to team. Some dogs, for example, are trained to work leashed, others unleashed, or depending on the terrain, both leashed or unleashed. The particular schools where the canines have been trained will not be further analysed in this study.

Methods
There are a number of standard methods to use when searching rubble with canines. Among the respondents, the methods are normally based on how the canine has been trained, the number of canines available, and the type of equipment that is used to locate the victim after a canine has made a detection. This combination of canine and technical equipment will be described further under heading *5.4 Combination of different USAR search methods and technical equipment.*

In this study, no further analysis will be made of any unique method's efficiency. Neither will any analysis be made of the pattern of how the canine or the canine handler moves when searching a site. This is due to time limitation, and also because rubble appearance differs so much in shape from case to case, that a generalisation would not be correct.

The different methods are divided according to how many canines and handlers that work together during a search. Each method is described under each category heading.

Search with one canine (Method 1)
A canine with handler, start to search a site. The search normally continues until the dog starts to get tired or unfocused. At that point, the handler takes the dog to a resting area, where the dog can eat, drink, and rest for a while. After a break, the search continues at the same place where it stopped.

If the canine detects a potential victim, there is no other canine to confirm it. Therefore, it is very important that the canine handler knows exactly how to interpret the dog's behaviour during a search.

Search with two canines (Method 2)
Among the investigated organisations, there are in general two different methods to carry through a search when using two canines.

The first method (2a) is conducted with one dog (dog number one) searching a site in the same way as described in section Search with one canine*,* while the other dog (dog number two) rests. The rescuers only use the resting dog to confirm the working dog's detections. When dog number one gets tired, dog number two takes over the search. After switching to dog number two the first dog can rest, ready to take over and support, in the same way as dog number two did before.

In the second method (2b), the canines work side-by-side at the same time in the same rubble. As before, the rescuers use the dogs to confirm each other's detections. The rescuers use this method if a site needs to be searched through quickly.

There are generally two strategic methods of using the dogs to confirm each other's detections. The first is to more or less direct the confirming dog into the area in which the other dog earlier marked a detection. This method is quite fast and if the dogs are able to sense the victim, they will probably mark it right away.

The other method is to let the confirming dog search through the rubble in the same way as the first one did. If the dog then marks the same area as the first, there will probably be detection of a live victim. However, problems occur if the confirming dog makes a detection in another part of the rubble or even no detection at all. In this case, the team leader has to make a decision on how to continue the USAR operation.

Search with three canines (Method 3)
There are several different types of methods for using three canines together. This section contains only a description of the two most common and general methods.

In the first method (3a), canine number one starts the search. When it has finished a search of a specific area, canine number two starts to search exactly the same area. This is done to confirm that there are no undetected victims in the area. Canine number three only confirms detections made by canine number one or two.

In the second method (3b), canines' number one and two work at the same time in the rubble as in the twosome system. Canine number three is only used to confirm detections made by canines' number one or two.

Sometimes when several canines work together, a canine team leader coordinates the search. The team leader takes a position at a point on the site where a good overview is possible. From that position, he can interpret a canine's behaviour and compare it with the other dogs. Based on this information, the team leader then coordinates the search through direct communication with the canine handlers.

5.2.1 Analysis of canine search methods

There are naturally different sizes of canines. The methods previously described can therefore be adapted to the size of the dog, for example, when searching a narrow pass a smaller dog would be more suitable.

Advantages of canine search methods:

Search with two canines

- If dogs are divided into pairs, it is possible to work on more locations at the same time.
- If one dog makes a detection, the other dog can confirm it, this to avoid spending vitally important time on a false detection.

Search with three canines

- Method 3a gives reliable detections as the same area is searched twice with two different dogs and a third dog confirms detection.
- This method always keeps one canine thoroughly rested.
- Method 3b speeds up the search of a site.

Disadvantages of canine search methods:
One main disadvantage of the canine search method is the cultural factor. In some cultures the dog itself is considered to be filthy and is therefore not proper to use during a search. International USAR teams have even been refused entrance to local property due to the presence of a canine. If a USAR team only bases its USAR work on the use of a canine, this could result in great problems when operating in areas with these kinds of cultures.

Search with one canine

- There are no other canines available to confirm detection. In the worst case, this could result in a time-consuming rescue operation after a non-existing victim.

Search with two canines

- In comparison, method number 2a is more time consuming than method 2b when searching a site.

Search with three canines

- Using one canine at a time as in method 3a is more time consuming compared with using them parallel to each other.
- A canine gets tired earlier with method 3b compared with the first. More breaks are required for the canines

5.3 Methods used with technical search equipment

For every type of technical search equipment, there are different methods for using each equipment to detect or locate victims. This section contains a description of these methods. Chapter *4 Search Equipment* provides a technical explanation of how the equipment works.

A description of how the different methods and equipment are combined will be further discussed in detail under the heading *5.4 Combination of different USAR search methods and technical equipment.*

5.3.1 Method used with sound or seismic detector

As mentioned in Chapter *4 Search Equipment*, the SSD (Sound or Seismic Detector) can depend on the other available methods and equipment, both function as detection and localisation equipment.

The method of how to use the SSD in action differs depending on how many sensors the equipment is able to uplink. In general, the procedure is the same but the major difference is if the equipment has two, or more than two sensors. Therefore, the description of the methods below is divided according to the number of linked sensors.

Using two sensors
At the start, the first thing the rescuers do is divide the rubble area into a grid. This is done so that they are able to orientate themselves in the rubble during the search.

The first deployment of the sensors in the rubble is done according to the axels of the grid, as in the illustration in Figure 5.1, preferably close to a previous victim indication. If there is no indication of a victim from the beginning, the sensors are arrayed at the base of the grid, at the perimeter of the rubble.

After the deployment of the sensors, their contacts with the ground have to be tested. This is done by tapping in the rubble a bit away from the sensors, at the same time as the operator listens for the tapping through his earphones, and reads the indicators. If the result is satisfying, a search attempt begins, if it not, the sensors are replaced, and the testing procedure is repeated. This goes on until the result is satisfying.

Then, for example, by knocking on debris with a hammer and listening for a response from a buried victim, an operator might get an indication of a victim. If there is no indication, rescuers move both the sensors. The rescuers move the sensors according to the intersections of the gird.

After the movement of the sensors, both the testing and searching procedure is repeated. This procedure (testing, searching, moving) continues until the whole rubble is searched through or until an operator gets an indication of a victim.

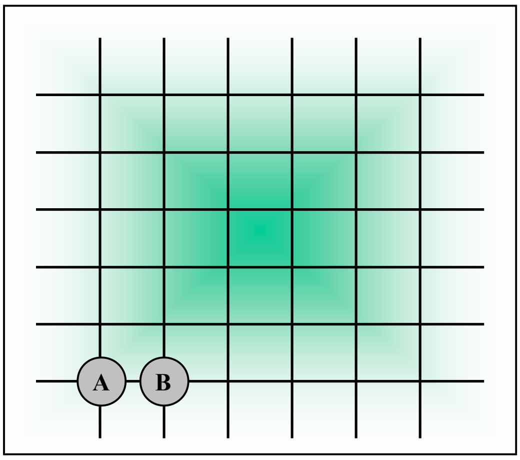

Figure 5.1 *Start position for search with Sound or Seismic detection.*

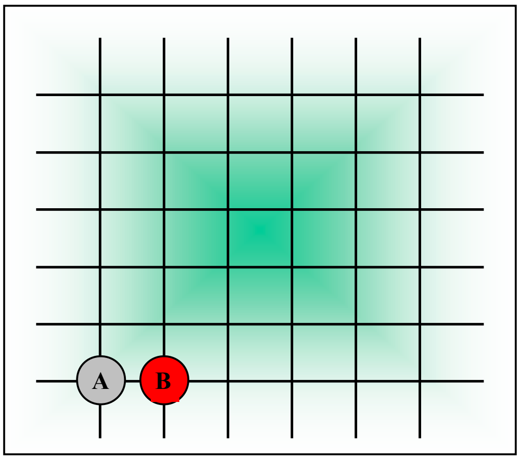

Figure 5.2 *The operator gets indication of a possible victim from sensor B.*

As shown in Figure 5.2, an operator can read an indication from sensor B that there might be a victim trapped somewhere in the rubble area (the senor is marked in red).

At this stage, the method of the search changes from a search for the detection of a victim, to attempting to locate the detected victim.

To proceed, the rescuers have to assume that the spot that has the best seismic or audible connection to the victim is the best point to start a rescue attempt and extraction.

To confirm that the area underneath the sensor that indicates a trapped victim has the best possible contact with the victim, the area around it has to be checked. To do so, rescuers move the sensor that has no or a weaker signal (in this case, senor A) and test it on the whole area around the sensor with the initially stronger signal (in this case, sensor B).

In Figure 5.3 this means that after sensor B shows indication, sensor A should be moved and tested, according to the intersections that surrounds sensor B in the grid. If rescuers do not pick up any stronger signal during this encircling procedure, they can be certain that the victim is buried either right underneath the sensor, or at the end of something that transfers the signal from a victim to that specific point in the rubble.

The sensors switch mode of application if a stronger signal is picked up during the test of the surrounding intersections. This is illustrated in Figure 5.4. During the encircling movement, sensor A picks up a stronger signal than sensor B. The procedure is then the same as before, but with movement of sensor B instead. At the stage when the whole area around a sensor has been tested and no stronger signal has been picked up, the rescue attempt can be started as before.

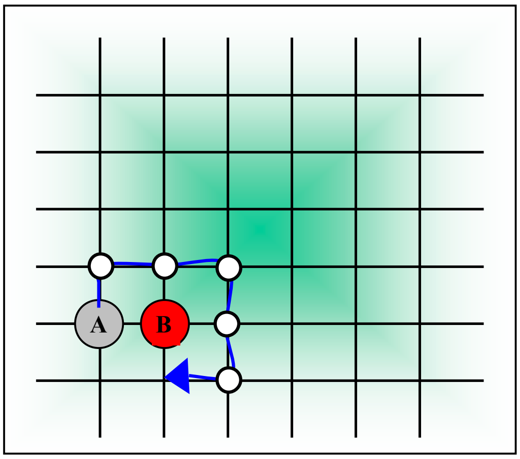

Figure 5.3 *Every intersection around a detection is tested for a stronger signal in an encircling procedure.*

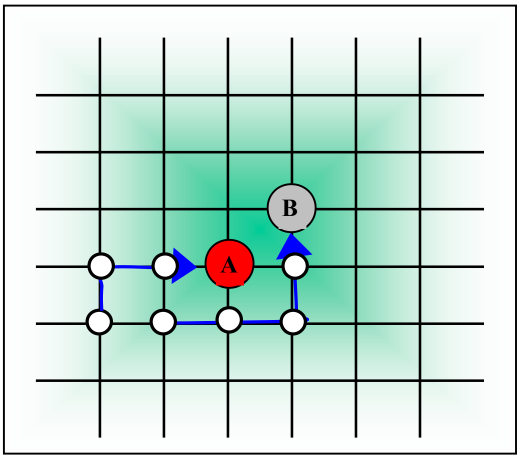

Figure 5.4 *The sensors (A) pick up a stronger signal than the original one during the encircling procedure.*

In the end, when every part of the grid is searched and there is no more indication, the search in that rubble with the SSD is completed.

Using more than two sensors
The method of procedure with an SSD linked with several sensors is generally the same as with an SSD linked to only two sensors. The major difference is that the operator controls several more sensors and, therefore, a larger area of the rubble can be monitored simultaneously.

In Figure 5.5, sensors are deployed a straight line in the grid. The sensors could even be arrayed in a pattern around a possible detection area or in any other way possible. This study makes no analysis of how the sensors are deployed in the starting sequence.

If no detection is made at the start position, all sensors are moved forward. After a second attempt, sensor C indicates a possible victim (Figure 5.6).

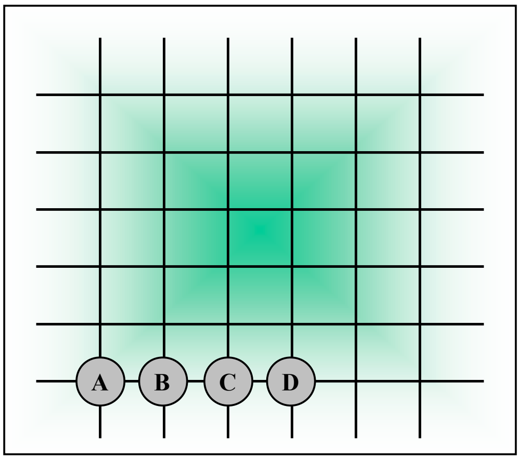

Figure 5.5 *The sensors' starting placement.*

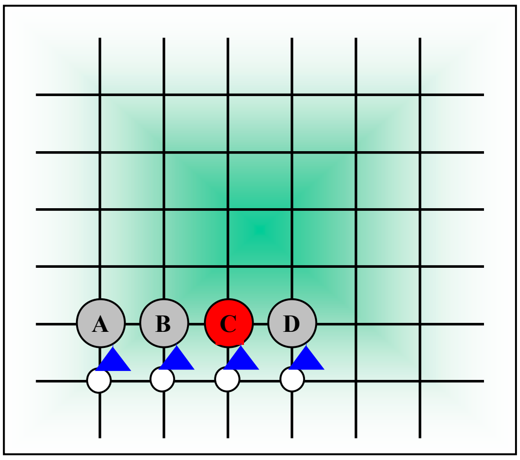

Figure 5.6 *After moving the sensors; sensor C indicates a victim.*

After an indication or detection, the procedure is generally the same as in the case with only two sensors. The other sensors are placed a bit closer to sensor C to encircle and decrease the possible area of location (Figure 5.7). By always moving the sensor or sensors that have no or weaker signals, the operator can, as previously, encircle a specific area in the rubble where the victim is probably located (Figure 5.8).

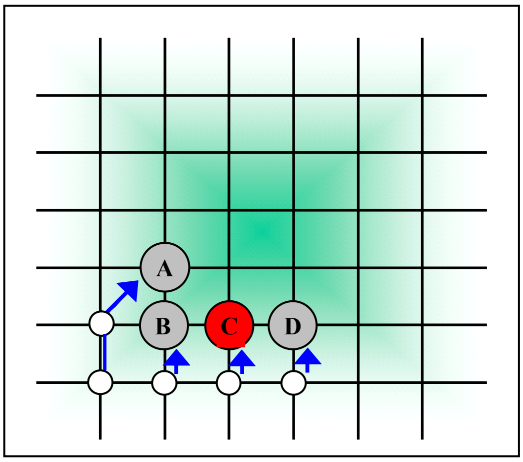

Figure 5.7 *The sensors are moved closer to the one with indication.*

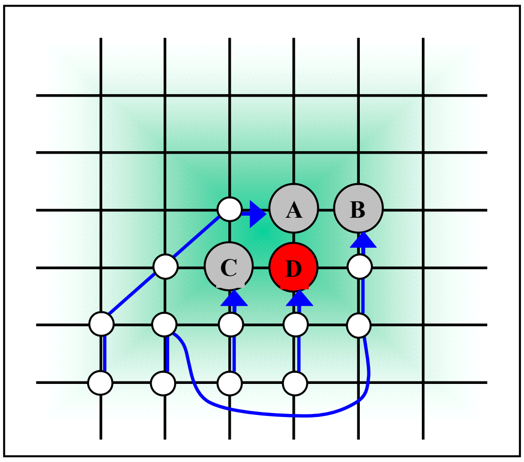

Figure 5.8 *As with two sensors, a possible victim location area underneath sensor D is encircled.*

5.3.2 Analysis of method used with sound or seismic detector

Advantages

- By moving the sensors through a grid system, rescuers can be certain that they have searched all parts of a site before marking it as complete.

Disadvantages

- The placement of the sensors is vital for successful detection. A poorly placed sensor with low seismological conductivity rapidly decreases the possibility of detecting a victim. Failure to test the sensors' connection to the ground after each movement can therefore be the difference between detection and failure.

5.3.3 Method used with infrared camera

From observations and responses there is no specific method used to search for victims in rubble with an infrared camera. Chapter *4. Search Equipment* provides a description of how this is done.

5.3.4 Method used with electric visual detecting device

From observations and responses there is no specific method used to search for victims in rubble with an electric visual detecting device. Chapter *4. Search Equipment* provides a description of how this is done.

5.3.5 Method used with fibre optic detector

From observations and responses there is no specific method used to search for victims in rubble with a fibre optic detector. Chapter *4. Search Equipment* provides a description of how this is done.

5.4 Combination of different USAR search methods and technical equipment

There are several combinations of methods and equipment used by international USAR teams. Because a search site is dynamic, conditions and information continuously change. The most effective way to use different methods and equipment is therefore to adapt them to existing conditions and the information received on a site.

The most frequently used combinations

According to responses, the most common way to perform a search are by using a combination of manual search, canine search, search with a sound or seismic device, and search with an electrical visual detecting device.

This combination of the different methods and technical equipment used during a search of a site follows a general schematic model of an event (Figure 5.9).

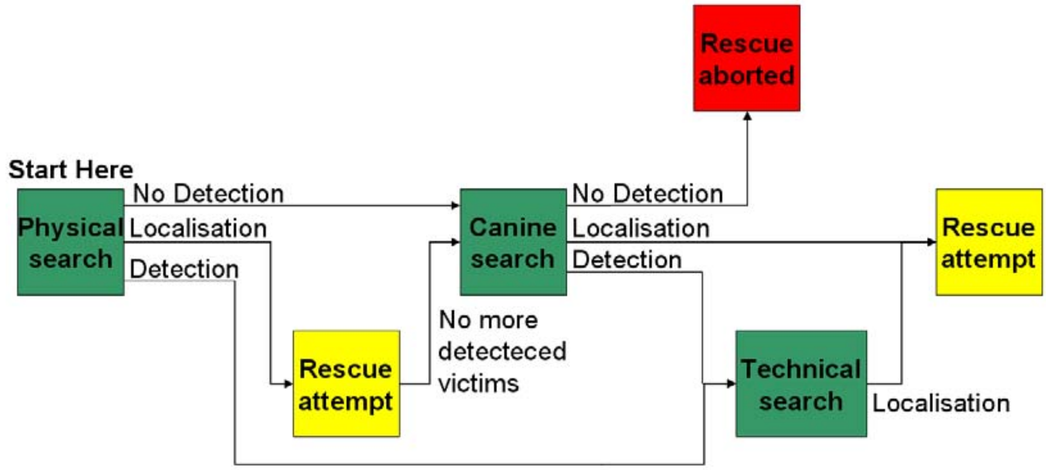

Figure 5.9 *Model of most common USAR method combination. The model is followed from left to right as long as there are indications that there could be a victim trapped in the rubble.*

The model starts from the left with the manual search and then continues to the right, depending on the events during the search. It is important to have in mind that this model only continues as long as there is information or indications that there still could be a victim inside the rubble. If other information turns up, the search is immediately aborted.

Each box in the model represents an action taken by rescuers. The outcome of these actions controls the next step of the search or rescue and the next step in the model.

The most common path through the model goes from physical search to search with canines. If the canines make a detection, it leads to a technical search. Through the technical search, the rescuers can locate and pinpoint the victim and based on that information start a rescue operation.

During the rescue, rescuers can also use the search equipment for tactical purposes, for example, the canines can be sent into a tunnel made for extraction to direct digging in the direction of the victim. For the same tactical purpose, the rescuers can drill a hole in obstacles and use the search camera to gather information on the situation behind the obstacles. In other words, this means that canines and some of the technical equipment can also be used during the rescue attempt phase.

Model adaptation
There are teams that do not use the search method with canines in their USAR operations. Instead, they rely on technical equipment for both detection and location, such as the SSD. In the model of method combination, this means that the canine search box and the technical search box unite as a technical search box, as in Figure 5.10. The model is used in the same way as with the canine search for the rest of the search.

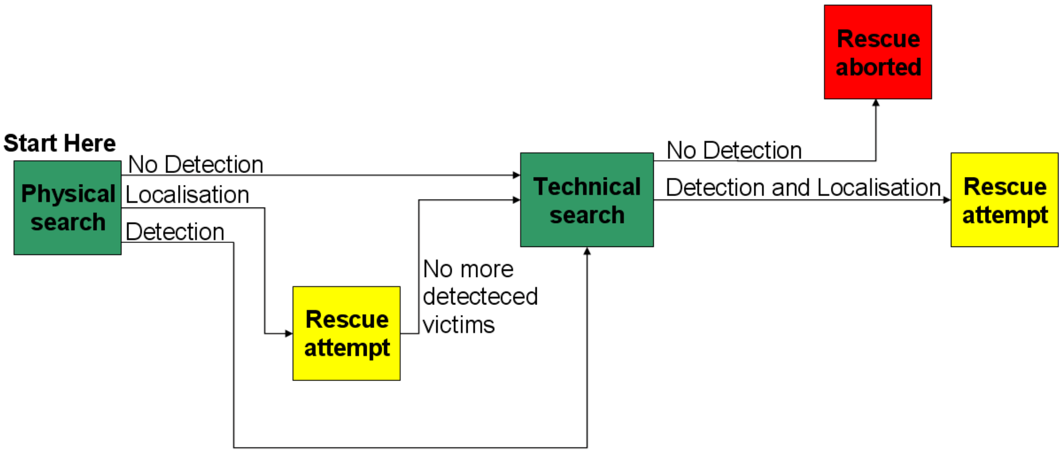

Figure 5.10 *Model of most common USAR method combinations without any use of canines.*

6. Quantitative analysis of responses to the questionnaire

This chapter contains an analysis of numerical data based on the responses.

All statistical information under this heading comes from the answers to questions 1,3 and 5-13 in the questionnaire (Appendix 1), unless otherwise stated.

The responses to the questionnaire are in many cases partial, especially regarding information about the time it takes an organisation to arrive at a disaster, and the number of sites they have searched.

6.1 Participating organisations

The following organisations participated in the study by responding to the questionnaire.

Tabel 6.1 Participated organisations.

Country	Organisation
Austria	Austrian Forces Disaster Relief Unit
	Fire Department, City of St. Pölten
Czech Republic	Ministry of Interior - General Directorate of Fire & Rescue Service of Czech Republic
Finland	Finn Rescue Force
France	Secouristes sans Frontieres
Japan	Secretariat of Japan Disaster Relief Team
Norway	Norwegian Search & Rescue Team
Poland	USAR of State Fire Service in Gdansk
Singapore	Singapore Civil Defence Force
South Africa	Rescue South Africa
Sweden	Swedish Rescue Services Agency
Turkey	Istanbul University Natural Disasters Search and Rescue Team
United Kingdom	British Civil Defence

6.2 Affected country and type of disaster

To be able to understand the extent of an operation, the respondents were requested to specify for each operation where the disaster occurred and what type it was. To avoid sources of error, only information from operations where the exact number of rescued ($\geq$0) were given were analysed.

Thirteen organisations replied to the questionnaire. All together, they provided information from 44 cases in which organisations participated in an USAR operation. These operations were not all unique; several of the organisations participated in the USAR work after the same disaster.

Table 6.2 shows the 20 disasters. Most of the reported disasters were earthquakes. Other disasters reported were building collapse, building explosion, seismic wave and snow slide.

Table 6.2 *Unique disasters that the investigated organisations have participated in.*

Affected country	Type of disaster	Date
Armenia	Earthquake	11 December 1988
Iran	Earthquake	20 June 20 1990
Philippines	Earthquake	25 June1990
Malaysia	Building collapse	16 December 1994
Russia	Building explosion	1996
Russia	Building explosion	1996
Austria	Building explosion	12 February 1999
Turkey	Earthquake	17 August 1999
Taiwan	Earthquake	21 September 1999
Turkey	Earthquake	12 November 1999
India	Earthquake	27 February 2001
Turkey	Earthquake	1 May 2003
Algeria	Earthquake	21 May 2003
Iran	Earthquake	26 December 2003
Morocco	Earthquake	24 February 2004
Indonesia	Seismic wave	26 December 2004
Thailand	Seismic wave	26 December 2004
Indonesia	Earthquake	28 Mars 2005
Iran	Earthquake	Unknown
France	Snow slide	Unknown

6.3 Arrival time of organisations after a disaster

When investigating the number of survivor distribution over time after an earthquake the 'golden 24' has to be considered. The golden 24 is a measurement of the predicted probability of finding survivors over time after an earthquake (Rosander). In general, the distributions show that after 24 hours, 80% of the extracted victims are still alive, afterwards the survival rate decreases rapidly (See Figure 6.4*)*

According to the golden 24, the time for arrival is vital for the organisations' ability to rescue trapped victims. Information about the disaster date and time and the time for the investigated organisations arrival is of great interest.
It should be mentioned that the time for the organisations' arrival is not equal to the time to action. Different problems like domestic transportation and logistics in the affected country can delay a rescue by several hours or even days.

Of all the specifically investigated operations, only the date and time for the organisations' arrival on scene could be determined from 28 of them. This difference is due to the lack of information in the responses. Accordingly, the arrival time could not be determined for all organisations.

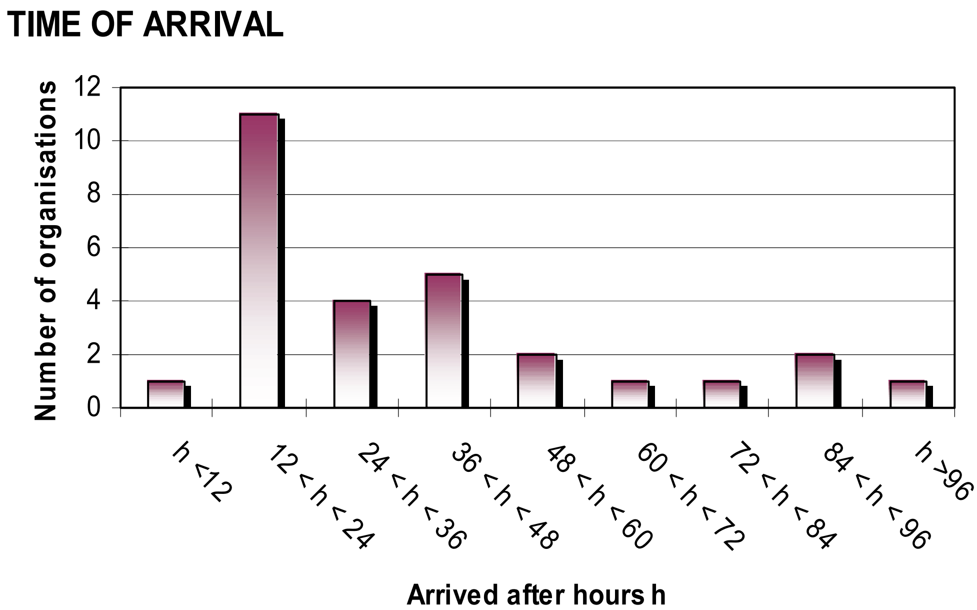

Figure 6.1 Plot of number of hour's h after the occurrence of a disaster until the organisations arrived at the disaster area.

Figure 6.1 clearly shows that most of the organisations arrived on the first day after the disaster (12 teams). The last two organisations to reach a disaster area, arrived four days after a disaster.

The fastest organisation to reach a disaster area arrived after only 10 minutes. To be able to arrive that fast, the team must be stationed close to a disaster area or already be working in it before it was affected.

Table 6.3 shows the number of days it took for an organisation to arrive to a disaster area. Within the first day, 43 % (12 organisations) of the organisations had arrived. A majority of the investigated organisations arrived within 3 days, 86 % (24 organisations), after a disaster.

Table 6.3 *Interval of the number of days after the occurrence of the disaster when the organisations arrived at a disaster area.*

Hour, h, of arrival		Number of teams	Percent of teams
$h \leq 24$		12	43 %
$24 < h \leq 72$		12	43 %
$h > 72$		4	14 %
	Total	28	100 %

6.4 Search equipment used by the different organisations

The search equipment used by the investigated organisations and the number of teams that used it is listed in Table 6.4. For a description of the equipment, see Chapter *4. Search Equipment.*

Table 6.4 *Type of search equipment and number of investigated organisations that use it.*

Type of search equipment used	Number of investigated organisations that use it
Canine	11
Sound or seismic detector	9
Electric visual detecting device	6
Fibre optic detector	4
Thermal image detector	4

Of the 13 investigated organisations, canine is the most common search equipment, a total of 11 organisations use it. The second most common is Sound or seismic device followed by the Electric visual detecting device, Fibre optic detector, and Thermal image detector. This means that of the 13 organisations there are at least two, which rely exclusively on technical equipment or only human sense for detection during operations.

6.5 Detection and localisation

The USAR methods and equipment that in the investigation have resulted in detection or localisation of a victim are:

- Visual detection or localisation
- Audible detection or localisation
- Sound or seismic detection or localisation
- Canine detection or localisation

In addition to the above, several detections and localisations are impossible to derive to any specific method. These are listed as ‘Unknown’. Table 6.5 shows data regarding when the teams have made a detection or localisation of a victim and what type of USAR method or equipment used during the search. The table also separates the different detections and localisations into daylight or darkness.

As localisations of a victim could have occurred without any method of detection, the numbers in the column *Detection* cannot be compared with the numbers in the column for *Localisation*.

Table 6.5 Time of detection, localisation and the type of method or equipment used.

		Number of victims			
		Detected		Located	
	Type of method or equipment	Daylight	Darkness	Daylight	Darkness
First day	The victim was visually		1		1
	The victim was audibly		1		1
	Locals pointed out the victim	1			
	Canine	1	2	1	2
Second day	The victim was visually	1			1
	The victim was audibly	2	1	3	
	Sound or seismic	1			
	Canine	1		1	
	Unknown	1			
Third day	The victim was visually	1		1	
	The victim was audibly		2		3
	Sound or seismic				1
Fourth day	The victim was visually			1	
	The victim was audibly		1		1
	Canine	1	2		2
Fifth day and after	The victim was visually	3	2	3	2
	Canine		1		1
Not known	Unknown	8	4		
	Canine		2		
	Sound or seismic				2
	Total	21	19	10	17

NOTE: The limited scope of the investigation, and the quantitative error distribution of equipment used by the investigated organisations makes it impossible to draw any exact conclusion on any one type of equipment's efficiency related to another, for example, a canine search in relation to a technical one.

Plotting data from the number of confirmed detected (See question eleven *Appendix 1 – The questionnaire*), related to the day when the rescues took place gives the graph in Figure 6.2.

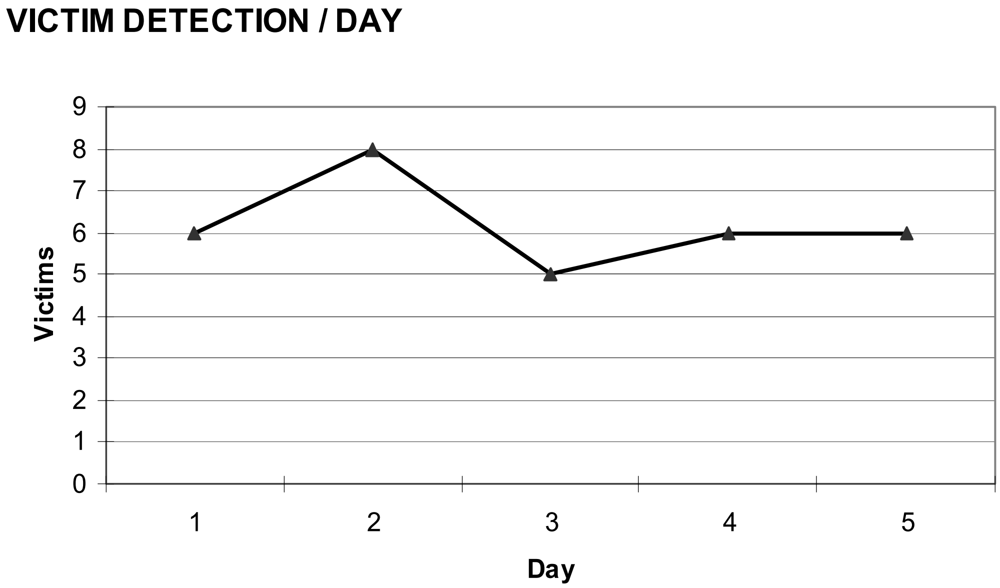

Figure 6.2 *Total number of detections of live victims under each day.*

Figure 6.3 shows a cumulative percentage detection plot of the data from Figure 6.2. The almost straight line in the figure shows that the percentage of the number of detected is near constant over time until the fifth day.

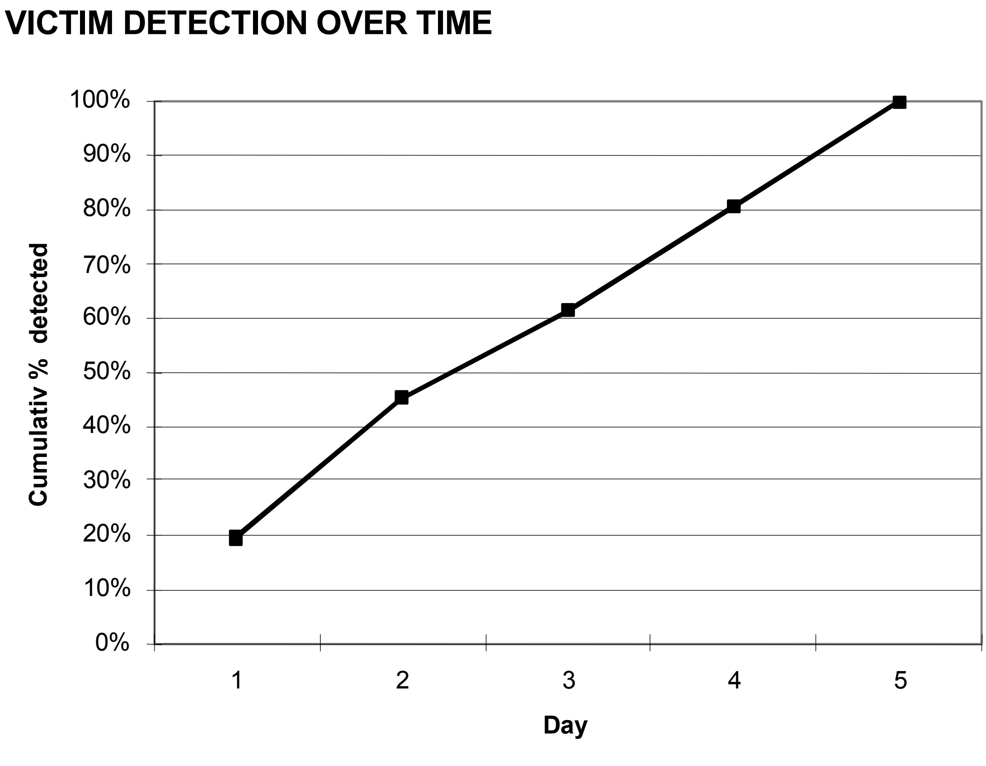

Figure 6.3 *Cumulative percentage detected over time, counted in days.*

In a study of the earthquake in Turkey 1999 (Rosander), the SRSA presents a diagram of the cumulative victim rescue distribution over time (Figure 6.4).

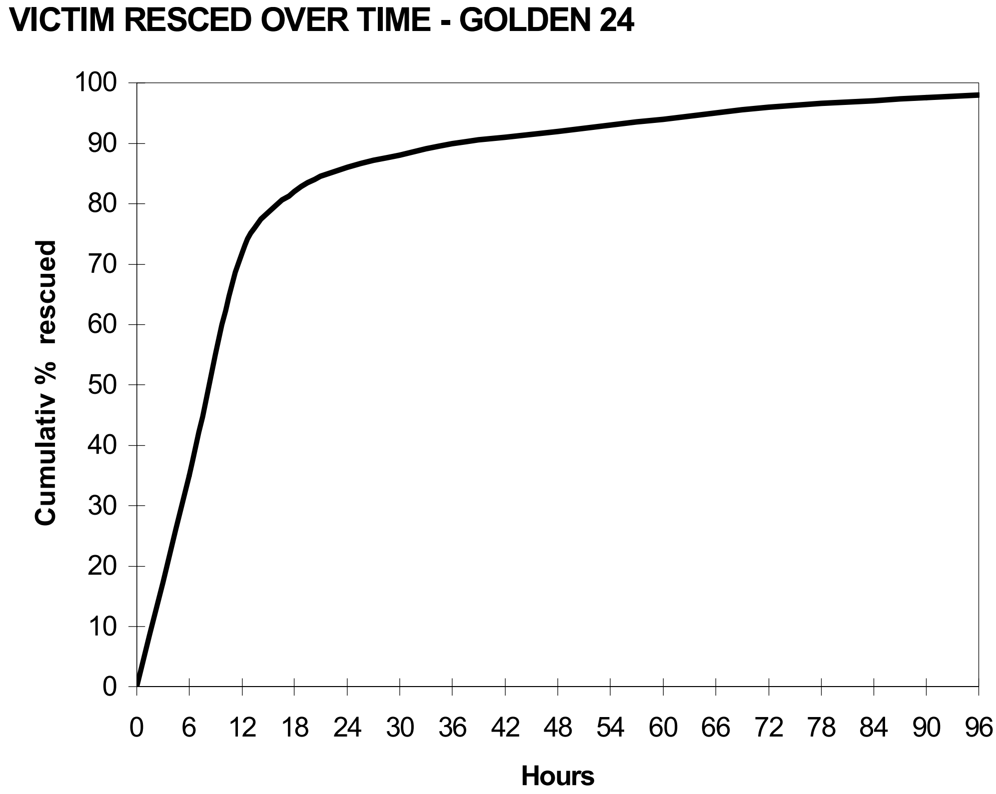

Figure 6.4 *Cumulative percentage rescued over time, counted in hours (Rosander, M., Svensson, H).*

As can be seen in Figure 6.4 more than 80 % is rescued with in the first day, then the number of rescued decreases. After the first day, the number of rescued per day is almost constant as can be seen on the straight-line after 24 hours in Figure 6.4. A comparison of the graph in Figure 6.3 with the graph in Figure 6.4 shows that the analysis of the number of detected in this report follows the same straight-line pattern after the first day (24 hours). This comparison strengthens the reliability of the number of reported detected victims in the questionnaires.

6.6 Search in darkness

In 28 of the 44 cases, organisations searched for trapped victims during hours of darkness. A summarisation of the data in Table 6.5 regarding light conditions, without any consideration to the time of rescue, are presented in Table 6.6.

Table 6.6 *Presentation of the total number of detections and localisations of victims, divided into the different type of method or equipment used.*

	Number of victims			
	Detected		Located	
Type of method or equipment	Daylight	Darkness	Daylight	Darkness
The victim was visually	5	3	5	4
The victim was audibly	2	5	2	6
Locals pointed out the victim	1			
Sound or seismic	1		1	2
Canine	3	7	2	5
Not known	9	4		
Total	21	19	10	17

It can be seen that the number of detections are quite similar. The analysis shows that the number of located victims differs by a factor of 1.7 depending on if the search was conducted during the day or at night. The factors that contribute to this remain unclear but it is worth noting for the development of future search methods and equipment and are therefore discussed in Chapter *10. Discussion*

7. General improvements

This chapter contains a summary of how to increase the efficiency of USAR search methods and technical equipment. Suggestions for improvements are based on responses to the questionnaire, observations and literature studies.

7.1 The search equipment

Electric visual detecting device

When searching for survivors in voids with either a video camera or an infrared camera, it can be hard for the operator to interpret the inputs from the video screen. In fact, it can be difficult to actually see if there is someone in the void or not, this is due to factors like poor visibility or near body heat environment temperature. In some situations, an infrared camera is more suitable for a search and in others; a normal video camera is preferable. For example, a dust covered body part can be much easier to spot with the infrared camera, while an ordinary camera is preferable in a near body heat environment.

A search camera, which allows the operator to switch from normal vision to infrared, would be preferable. This would give the operator the potential to work with the type of view that gives the best information for the moment. Due to the number of affecting factors, this system combination would not help in all poor visibility situations, but several more than with only one kind of system.

A system combination would most likely also affect the purchasing cost negatively, which is listed above as a disadvantage for this kind of equipment (See heading *4.2.1 Analyse of electric visual detecting device*).

Fibre optic detector

A well-known major problem for operators handling a fibre optic camera is to orientate themselves inside the rubble. One way to facilitate this is to equip the camera with a 3D positioning system that shows the exact location of the camera head.

Sound or seismic device

Current searches with the SSD totally rely on an operator's interpretation of the sounds that the equipment is able to pick up. On the most types of SSD, the operator is able to filter different frequency bands, thus removing disturbing background noise. Then by moving the sensors according to a grid, the operator can determine possible victim location areas.

If the operator, at an initial stage, had the opportunity to filter among all unique sounds that the equipment picked up, he would be able to remove a lot more of the disturbers and at the end be able to amplify a unique sound sent out by a trapped victim. After doing this, the equipment would be much more resistant to disturbance during the rest of the search.

This type of filter program is already available on the market in basic PC sound sampling programs. Conversion and implementation of this type of program into future equipment would therefore probably not lead to any significant purchasing costs.

Using the same type of triangulation that Arai (2001) uses in his search equipment would give the SSD operator a calculated possible location of a victim. Together with better filter opportunities and by using this digital triangulation system, the operator would be able to detect and locate a victim with better accuracy and less influence from human factors.

However, this system would be far from entirely reliably. As rubble in most cases are inhomogeneous, vibrations or sound signals from a victim will spread to different ranges in the rubble. This will lead to an incorrect position finding. Yet, the SSD is not currently a system used to pin point victims’ position in centimetres, rather the SSD provides rescuers with an indication of where to start a rescue attempt.

Knowledge of the equipment
Observations of exercises revealed that many teams have limited knowledge of what kind of equipment the other teams use or how it works. Neither do they have any knowledge of the other teams’ equipment limitations and advantages. This lack of knowledge of the other teams’ methods and equipment might cause a less efficient search than if the teams used their collected resources via collaboration.

Future Equipment
During the research for this report, several ongoing research projects around the world with the goal of developing equipment to search for and find victims buried in rubbles were investigated.

A short summary of some of these projects follows.

Neural network
The SRSA have together with the Swedish Defence Research Agency developed a prototype for an electronic nose (Jubrink 1997) (Jubrink 1998). This system was primarily intended as an alternative to the canine method. The method detects humans by using gas sensors, neural networks and computer software. Test results show that this system probably might be useful in the future. Unfortunately, SRSA could not provide further financial support to the project.

Ground Radar
Ground radar is equipment under development. According to Arai (2001) it can detect the breathing from a human under 1.5 m concrete blocks. If this research project is as promising as Arai states, this equipment could be very useful in future USAR operations.

Search Robots
There are several research projects investigating search robots. Primarily these robots are meant to be used in areas humans cannot access. It would be too time consuming to analyse all types of search robots that are under development therefore no further analysis has been conducted.

7.2 The search operation

Training and planning for an operation
As mentioned in Chapter *3.1 Methods*, the documentation from the previous USAR operation is poor, especially information regarding victim rescue. For the purposes of this report, most data had to be collected through a questionnaire and observations. This information would have been easier to gather if it had been in written reports. This factor clearly shows the difficulties the organisations encounter in learning from each other, and by that, an easy way to be better prepared and trained, when arriving to a disaster area.

Command
One lesson learned from the EUROSOT 2005, is that without a proper chain of command and on site coordination, even in a controlled situation, an operation easily gets out of control. The result of that is confusion and misunderstanding on the part of teams and organisations. This observation is something that respondents mention in questions 14 to 17 in the questionnaire, as vital for a successful operation.

During EUROSOT 2005, the chain of command was disregarded several times by the teams. Rescuers made decisions without any involvement from any commander, with disorder as result. The Major Incident Medical Management and Support (MIMMIS, 2002) clearly states that a distinct chain of command and cooperation is essential for an effective operation during a disaster. Cedergårdh and Wennström (1998) write that without the right command problems can occur that are serious for the general picture. A faulty routine can, in unclear conditions, result in grave and unwanted consequences.

On field disturbance
The importance of a quiet search area has been mentioned above. Despite this, almost every respondent says that they have been disturbed during a search by factors caused by other humans. In some cases, the disturbance has even come from other USAR teams in the area around or in the same rubble.

Observations from EUROSOT 2005 clearly show that more authoritarian on sight commanders and better-trained team leaders could easily avoid the factor of disturbance from, at least, other teams.

Information on site
According to respondents, the most important thing for a successful USAR operation is information provided by locals on site. On several occasions, locals were able to provide vital information about victims inside rubble. Gathered on

site local information has helped to determine the number of victims buried inside rubble and even their possible location. This type of information is of great interest when rescuers plan a USAR attempt on a site.

However, the information from the locals should always be handled with care, as there could be locals trying to cause the rescuers to search for missing family members. Alternatively, there may be locals who try to manipulate rescuers not to search a specific building, even though there could be possible victims inside, and instead, search for the local's family members.

Nevertheless, rescuers have obligation to inform locals about how their methods and equipment work. This is something that strongly relates to the above factor of locals disturbing the search. It is not possible for locals to know how to act if they are not informed. There are even some cases in which there has been irritation and anger among locals because they perceive the rescue work as not efficient enough. One conclusion is that not enough effort can be spent on informing locals about the teams' USAR work, how the locals should act, and how they can help.

Other types of information required to speed up a USAR operation are information and identification of the affected buildings. One respondent suggests that in the future a trained specialist from the affected country could gather and give this information at a stage prior to the teams' arrival. Some frequent earthquake-affected countries already educate their inhabitants on how they should act during and after an earthquake (KAMEDO 73, 1999). One suggestion is that some kind of structural recognition education of persons in authority could be a part of this training.

Completing a site

When USAR teams use a structural marking system with different types of methods and equipment when they search through rubble, this will lead to various levels of accuracy for the search. One team that uses one kind of equipment might not find anything on a site, while another might find survivors with their equipment, if the search was done on the same site. Consequently, the first team would mark the site as completed without finding the buried victims.

One way to reduce this problem (that actually has been experienced by the respondents) is to set up requirements for the extent of a search before a site is finally marked as completed. Yet, to do this the efficiency of methods and the equipment must be further examined.

7.3 Reporting

System of reporting

The Swedish National Audit Office (Riksrevisionsverket, 2001) writes that a lack of cooperation causes the risk for sub-optimisation by the organisations, i.e., that the entire organisation suffers from the priority of individual units. The observations and the questionnaire show that this is what is going on among the international USAR teams and organisations today. The system of reporting to other USAR team is in many cases deficient, if it even exists. As mentioned above, without the proper reporting system it is almost impossible for an organisation, a team leader, or a rescuer to improve themselves through lessons learned during operations. (See Chapter *8. A learning organisations and future model of reporting*)

8. A learning organisation and future model of reporting

This chapter contains an explanation of problems without proper reporting. It also contains suggestions for information that is essential for the development of better USAR strategies.

8.1 A learning organisation

A learning organisation is an organisation that continuously endeavours to adapt and develop within their environment of existence. Skyrme (2005) lists the following vital characteristics of that particular type of organisation.

- Are adaptive to their external environment.
- Continually enhance their capability to change or adapt.
- Develop collective as well as individual learning.
- Use the results of learning to achieve better results.

Argyris (1996) describes the learning procedure within an organisation with events called Single-loop learning (SSL) and Double-loop learning (DLL). These two types of organisational learning procedures are separated by the organisations' method of handling advancement. Figure 8.1 shows an illustration of the loop-learning organisation.

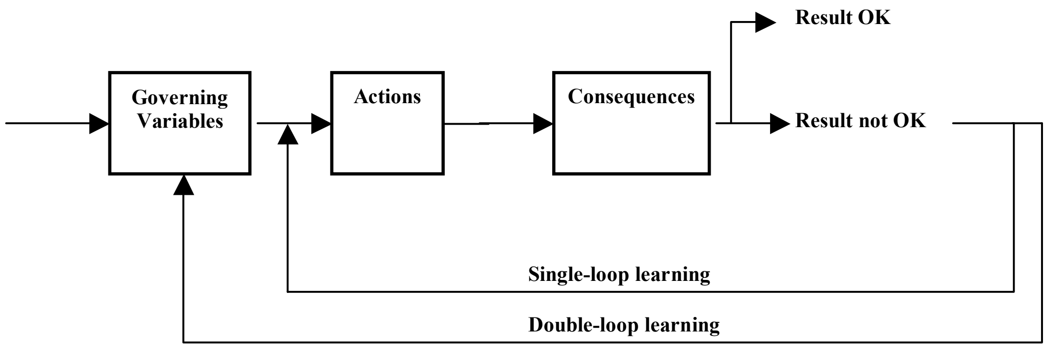

Figure 8.1 *Simplified model of Argyris's learning organisation based on model from Koornneef, F., (2000).*

Argyris's (1996) SLL implies that an organisation changes its behaviour according to results. A divergent result leads to a change in actions until the organisation finds a solution that obtains a satisfying result. In other words, all other solutions that have been tested and failed are rejected. The lessons learned from this procedure stay within a limited element of the organisation. This means that no other part of the organisation gains any knowledge of this advancement. A similar event in another element of the organisation will lead to the same testing procedure as before, even though the solution already exists.

Argyris's DLL, implies that the organisation in its entirety strives to attain learning and development. The whole organisation analyses acts, and gains knowledge of divergent results and action taken. To attain better results, the organisation continuously questions the governing variables to attain better solutions than existing ones. (Skyrme, 2005)

8.1.1 Dangers of the learning organisation

A DDL organisation is not only positive. If advancement and solutions to problems are not treated correctly, the DDL process can cause serious damage. Blackman et al (2004) describe this problem with the DLL in their article *Does double loop learning create reliable knowledge?*. They state that the DLL requires proper testing and scientific evaluation of the theories in use. If not, this can lead to implementation of an incorrect theory in the organisation. As a result, the knowledge inside the organisation would be built on untested or even false justifications.

Blackman et al (2004) also point out the problem with closed organisations. Controlling knowledge and keeping it from critical scrutiny can aggravate the result of a theory, rather than improve it.

8.2 Learning model of today

If the model in Figure 8.1 is applied to the USAR work of today, the research shows that the progress and developments that different teams make often stays within their own organisation. Learning by the different teams and organisations is therefore very similar to the SLL process. Little effort is made to spread advancement and knowledge to other organisations. Research also reveals that even if an organisation actively searches for others' progress, the information and available reports are, with some exception, deficient. In the end, this means that global USAR work fails to secure the synergy effects that can be achieved throughout better collaboration between international USAR organisations.

Today, learning is not entirely based on the SLL process. Many of the investigated organisations use similar types of methods and equipment, in many cases even the same equipment manufacturers. The implementation of this equipment is probably based on some type of learning process that is more spread among the organisations then the SLL. However, no scientific investigation of equipment efficiency has been found during this study. The problems that Blackman pointed out with the DLL process might therefore already have been implemented.

8.3 Facilitate the dissemination of information

Improvement of the dissemination of information among the organisations lies on an administrative level. A better model for reporting and documentation would increase the ability of other organisations to take part of the lessons learned from USAR operations. As it is today, the reporting by several organisations of the scenarios and the lessons learned from the rescues are deficient. Others that have developed a model for reporting and documentation only have it in their country's language. This makes it difficult for others to take part of it. A standardised model for reporting and documentation in languages used worldwide would increase the potential to disseminate this kind of information.

8.4 Model of future reporting

This section contains a description of how an efficiency comparison model can be built up from reported information from USAR operations, and also how the model could be extended in the future.

8.4.1 The base of the efficiency comparison model

During the analysis of results from earlier USAR operations, the following information has been assumed as essential to be able to build a reporting model and to be able to compare the efficiency of different USAR search methods and equipment.

- The day when the rescue took place.
- Type of structure that is searched.
- The detection method and equipment used.
- The localisation method and equipment used.
- Number of rescued and the number of deceased on the site or in the object.

Due to that the chance of finding victims alive varies over time (see Figure 6.4), the first step is to report when the rescue took place *Day of Rescue*, counted in days after the disaster. The second step is to identify the *Type of structure* of the search rubble. This should be carried out as there are varying chances of finding survivors in different types of structure (UNDAC, 2002) and therefore identifying the structure that makes up the rubble to be searched is vital for the model. Information on *Detection method / equipment* and *Location method / equipment* is needed to be able to ascertain their efficiency. The *No. of rescued / deceased* at a site or in an object is needed to be able to statistically compare the efficiency of different methods and equipment.

Simplifying the model used in *5.4 Combination of different USAR search methods and technical equipment* and expanding it with the above factors, the new efficiency comparison model would look as follows in Figure 8.2

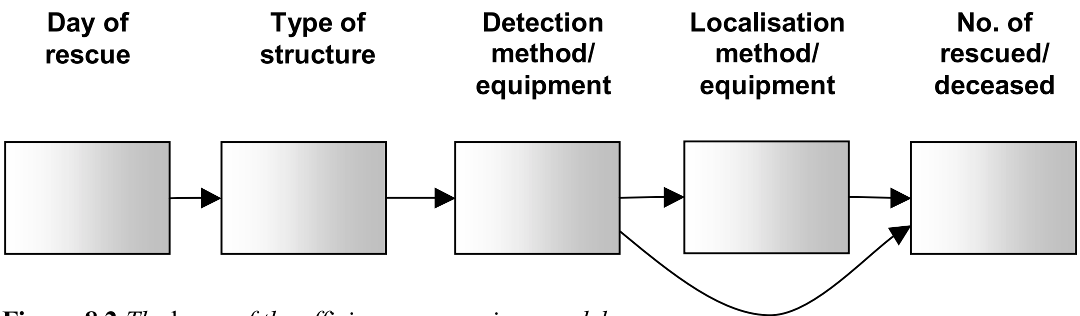

Figure 8.2 *The* b*ase of the efficiency comparison model.*

8.4.2 Using the model for efficiency analysis

How to use it as first base for reporting

The model should be used for statistical analysis of the efficiency of different search methods and equipment. To do so, the model in Figure 8.2 should be transformed into the structure of a decision tree. This is accomplished by letting every step in the model represent a step or decision in the tree (For more information about the decision tree, see Mattsson, (2000)). After this, the structure of the model gets the appearance as shown in Figure 8.3. At this stage, the model is ready for use as a basis for reporting.

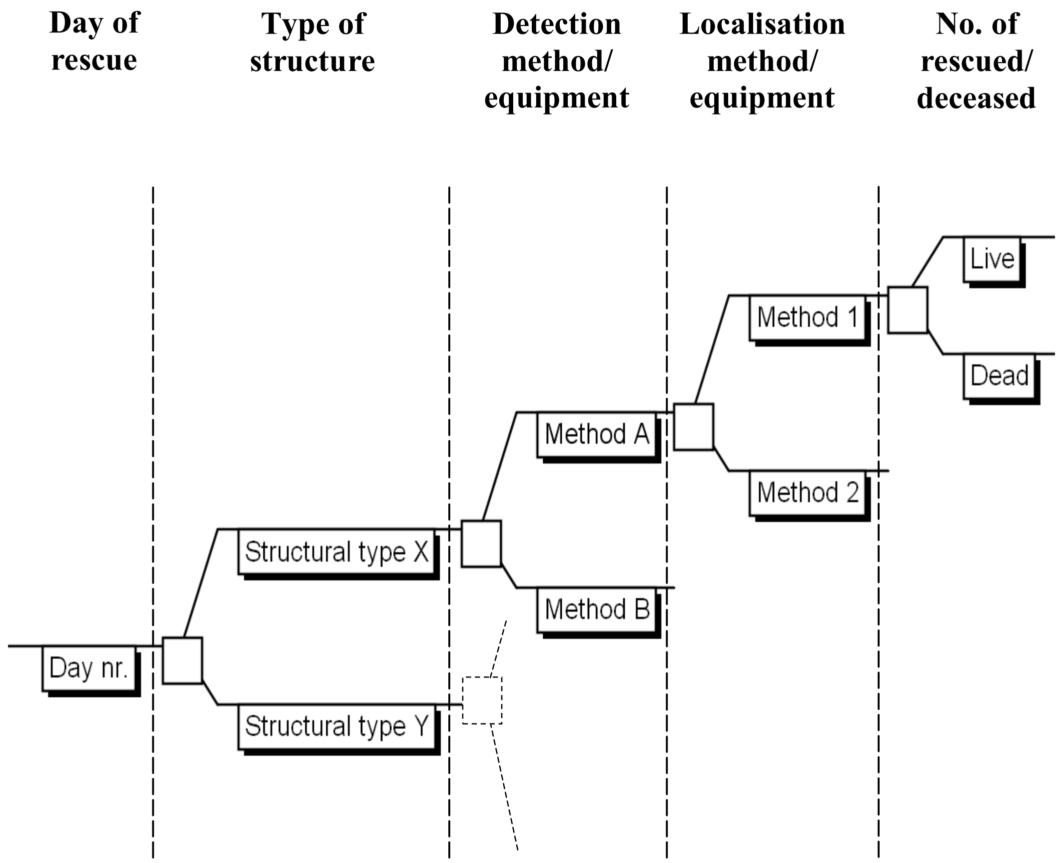

Figure 8.3. *The efficiency comparison model converted into a decision tree.*

Information on how a search has been conducted is reported by following the model from left to right. Then the number of rescued and deceased is filled in at the right. A comparison of the number of reported rescued and deceased gives the probability that a person trapped inside of that specific type of structure is rescued on that certain day after the disaster, with that specific detection and location method or equipment combination. For every search that has led to new information about the number of rescued and deceased, the specific probability for survival needs to be updated by using *Bayesian Updating* (Ryhlik, Rydén, 2004). After adding information from several different situations and after several updates, the model could appear as in Figure 8.4 . (The numbers in the figure are only examples, are fictitious and are not related to reality.)

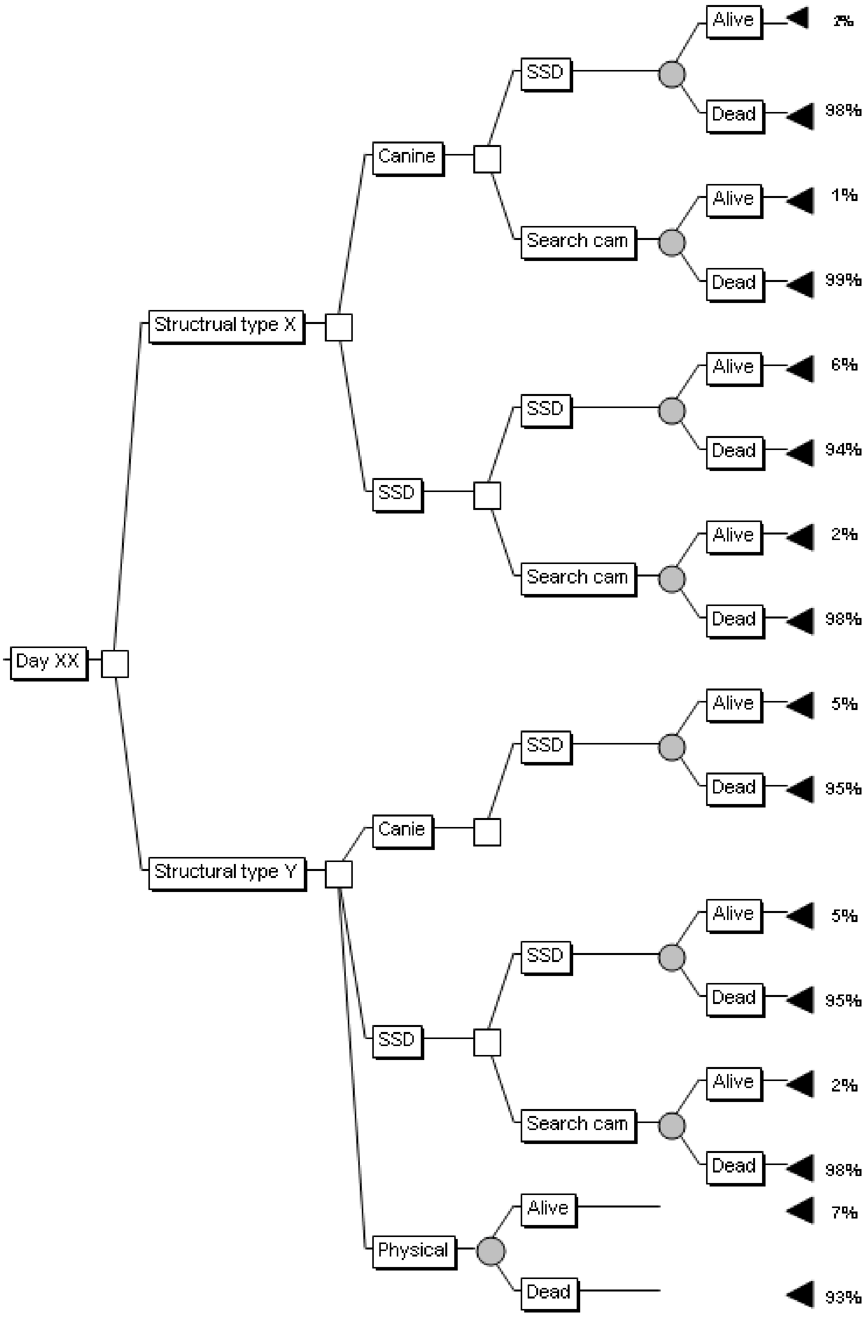

Figure 8.4 *Illustration of how the efficiency comparison model could look after being updated.*

How to use the data in the model

Before using the data in the model, it is vital to remember that the results of the model can only be used to compare chances for survival related to other method combinations in the same type of structure. In other words, this is not a real number of the chance for survival, only a measurement of the efficiency of specific combinations related to each other.

Data and results from the model are very easy to use. Given that a person is inside a specific type of structure and a disaster occurs which leads to that the building collapses and buries the person, dead or alive, the model clearly shows what type of rescue procedure that gives the highest probability for that person to get out of that rubble alive. For example, according to the illustration in Figure 8.4, the best way of searching a collapsed structure of type X after XX days is to use a combination of Canine and Search Camera.

This information could be useful, for example, for a team leader at the starting point of a rescue attempt in rubble. Having this information the leader would know what type of methods and equipment that should be used to obtain the greatest chance of finding a victim or ensuring that there are no live victims left inside the rubble.

8.4.3 Model expanding factors

The model is not being totally reliable as long as it only shows information from successful rescue attempts. Information must be gathered on how many times each method and type of equipment fails to locate a victim. This would also give the team leader information on which method combination that has the greatest probability of failing to detect or locate a victim. In the end, this could mean that the team leader tries more then one method to be certain that there are no live victims left in the rubble.

To make the model even more informative, information regarding circumstances during the particular rescues could be added, for example, such as arrival times to a disaster area, weather, wind, light conditions, and time of day. This is of interest because some methods or equipment might work better in some special environments. For example, the results in this study indicate that the chance of locating victims in rubble is better in darkness than in daylight.

8.4.4 Model related problems

The model does not take any consideration of victims' sex, age, physical health or when they were rescued, factors that are all vital for a victim's probability for survival. It would be easy to add this type of information to the model, but unfortunately, the more information that is added to the model, the more the model expands. This provides more results on the model and therefore reduces the statistical basis for each case that results in a less correct value for the results.

Other problems are new methods or equipment that are introduced to USAR work. By chance, theses methods or equipment can after a first search be more or less efficient than other methods or equipment already implemented into the model. An incorrect higher probability will level out over time as the method or equipment is used. An incorrect lower probability might stay low, as no teams want to use a poor search method. This could result in that the method is never further tested or implemented by USAR teams.

However, if a new method or type of equipment is scientifically proven to be more effective, it would with adaptation and proper organisational double loop learning, quickly be implemented and therefore used more often, and in the end level out the lower probability differences in the model.

The greatest problem with the model is probably obtaining information on how many people that died inside rubble. This might be information that cannot be produced until many months after the search operation is completed. Therefore, the collection of this type of information has to be centralised to an overarching authority to ensure that every participating organisation reports the requested information.

9. Conclusions

- The most common search method and equipment that the investigated teams use is a combination of physically search, canine search and technical localisation equipment.

- Today it does not exist any type of common reporting system for lessons learned during USAR operations, neither any spreading of information on USAR research and development. A better reporting and documentation system would increase the ability for the organisations to share their experience. To avoid that vital information fails to be secured in the future, a common reporting model for international teams should be implemented as soon as possible.

- The effect of the previous international organisations' USAR work cannot be determined without time-consuming procedures.

- Progress and developments that different teams make, often stays inside the different organisations. If double loop learning were used among international organisations, that problem would decrease.

- The scientific analysis of the USAR search methods and equipment used today is too defective to be able to determine the equipments efficiency. Therefore, more research is needed to ascertain the efficiency of today's technical search equipment and search methods.

- More locations of live victims have been made in darkness then in daylight, according to the quantitative analysis of the answers to the questionnaire. To ascertain if the conditions of detecting and locating live victims are better in darkness or "night-time search" a more extensive evaluation is needed.

10. Discussion

Questionnaire

Great effort was invested in choosing and formulating the questions and making the layout as attractive as possible. As mentioned in Chapter *3.1.5 The Questionnaire* before it was sent out, the questionnaire was analysed by SRSA personnel with knowledge of the area of USAR, and the SRSA's translator corrected the language. Still, some of the questions could have been misunderstood, incorrectly formulated or even unnecessary.

The respondents seemed to have most difficulties filling in information about the exact time of the team's arrival and how many objects or sites their team searched through an operation. The reason for this problem could be a misunderstanding, an incorrectly formulated question or poor reporting.

Respondents were asked to fill in information from several different operations that their organisation had participated in. It would probably have been better to analyse only one specific operation, then the conditions would have been more equal for all the teams and an analysis would therefore have been easier to make and the results would have been more correct. Nevertheless, the exact time of arrival, time of detection and time of localisation and more is needed. To gather this type of information, a proper reporting system is needed or an interview of the personnel involved in that specific operation.

It would have been desirable to ask more questions about how detections and localisations were made to be able to ascertain the efficiency of today's search equipment and methods. However, more questions could have resulted in fewer responses. Consequently, to get the best response, the questionnaire was not extended with more questions.

Statistics

To be able to do a statistical evaluation, it is important to have enough material to work with. Thirteen questionnaires were filled in and returned and information from 44 operations was reported. This is probably not enough to statistically ensure the results but still valuable information can be gathered.

Victims

The definition of victims in the research does not include deceased victims or animal victims. However, some of the respondents have the opinion that the USAR teams should rescue animals and extract the deceased.

If teams actively search for deceased, they tie up resources that could be used at other places to search for live victims. To be able to rescue as many lives as possible, an active search for deceased victims should be performed at a stage when it is most likely that there are no more survivals left in rubble. On the other hand, there are cultures that value their deceased as high as the living. Therefore, based on cultural factors, the teams must decide for each operation whether or not they should perform an active search for deceased victims.

No consideration has been taken to animal victims in this study. However, in poor countries animals like cows, chickens and pigs can play an important role for a family's survival. Rescue of a human victim has a higher priority than animal rescue but rescue of cattle could help several more victims to survive after a completed rescue operation.

Disparity of distribution

The number of detections and localisations that were made must be put in relation to the number of organisations that use the different methods or equipment. Canines are used by 11 of the 13 investigated organisations. The number of detections and localisations is therefore most likely greater with canines then with other search equipment.

It is not apparent that an organisation, which has responded that they own specific equipment, has used it during previous operations. If not, that could be the reason why no detection or localisations has been made or reported with that particular type of equipment.

Daylight and darkness

The quantitative analyses of the answers to the questionnaire indicate that there have been more locations in darkness then in daylight. This could be a coincidence, teams that do not usually search in darkness may perform the search because detection has been made in daylight but without localisation, and therefore, the search is continued in darkness. However, there are several reasons why these results could be correct.

- A search site can be very noisy in the first days after a disaster, especially in daytime or daylight. When darkness falls, the noise level might decrease as the intensity of the rescue work is reduced. Trapped victims that could not be heard earlier may have a better chance of being detected in darkness.

- Another reason could be that temperature decreases during darkness. *"In darkness, the S.A.R dog can search more effectively than its human counterpart, because the victim is often more detectable at night, in the cooler air."* (Beaver, 1990)

To ascertain if the conditions of detecting and locating live victims are better in darkness or "night-time search" a more extensive evaluation is needed. If this proves to be correct, both the search equipment and search methods should be adapted for use in both or either daytime or daylight and nighttime or darkness.

Improvements (investments)

If investments were made in improving and making the search equipment and methods more effective, this would probably result in an increased probability in rescuing a trapped victim and thereby the total number of rescued during an operation. However, there may be things that could increase the number of rescued victims even more.

It costs a lot of money to send a USAR team with equipment to an operation. It is almost impossible in advance to know how many lives they will be able to save. It may be so that more lives would be saved and the cost per saved life would be less if only medical teams for emergency treatment were sent. Instead of investing in better search equipment and methods perhaps it would be better to use these resources to increase the capacity to send more emergency treatment.

Frederick Krimgold writes that relief could function as more then just relief. *"In some cases it serves to gain a foot-hold within a particular developing country to encourage the development of diplomatic and economic relations."* (Krimgold, 1974). In other words, Krimgold states that behind the decisions of sending relief, there is also a lot of politics involved especially for government organisations. For example, countries that send some kind of relief to a country affected by a disaster show the country and the rest of the world that they care. This could in the future strengthen the relations between the countries.

Information
As described in Chapter *8. A learning organisation and future model of reporting* the research shows that the progress and developments that different teams make often stays within their own organisation. To be able to share this type of information the organisations needs to agree on how it should be done. This is of course if the organisations are willing to share the information. One solution could be to have a standard on how the documentation should be done. INSARAG could then take the responsibility to distribute the information to both members and non-members.

Efficiency
The BCD (British Civil Defence), founded in 1967, with great experience of USAR, writes under the heading "High Tech: Toys for the Boys?" that technical search equipment use in today is highly questioned. The BCD is of the opinion that the equipment does not work effectively enough, they say that, *"In most cases these hi-tech toys are used to impress governments and local populations and create the illusion that the team in question is very professional. In many instances nothing could be further from the truth."* (Stanton, 2002)

Maybe there is no technical search equipment that is effective enough today. Instead of sending the most high tech equipment that exists, it may be better to use only basic manual search methods.

An investigation of today's technical search equipment is needed to ascertain their efficiency. The same should be done with search methods.

It would have been great if the results of this study could have shown which search equipment and methods are most effective in detecting and locating victims. Unfortunately, many factors influence the results, for example, building construction, weather, different types of rubble, resources, and information from locals. Due to the complexity of the factors and the poor reporting concerning detection and location from earlier operations, such information is hard or sometimes impossible to find. It has therefore not been possible to ascertain the efficiency of equipment and methods.

To be able to do so, a better reporting system would be a solution. Nevertheless, it is not certain that a reporting model is enough to make a scientific evaluation. It is hard or even nearly impossible to make a reporting model that considers all factors that influence results. Another solution would be to test each type of equipment and method under the same conditions. With a better reporting model and testing under same conditions, it would be possible to evaluate the efficiency of each type of equipment and method. Equipment and methods that do not work sufficiently could then be improved or even taken out of service.

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Appendix

Appendix 1 - The questionnaire

RÄDDNINGS VERKET

Swedish Rescue Services Agency

Urban Search and Rescue Methods and Technical Equipment

This questionnaire is aimed at personnel with experience of USAR (Urban Search and Rescue) operations.

The responses to this questionnaire will be used as the basis for a master thesis on the subject of USAR. The purpose of the thesis is to identify the methods and equipment that are most effective in the search for live victims in rubbles and to provide suggestions on improvements for existing methods and equipment.

The report, containing the results, will bee available to all INSARAG members and to other foreign USAR teams in January 2006. We hope that the results of the report can be useful in the research and future development of USAR methods and equipment.

To maintain objectivity in the thesis the responses to this questionnaire will not be published with any reference to you, your organization or your USAR teams, but rather with a reference number and a summarized list of participating organizations. Your opinions and answers will be held in confidence.

This project has been assigned to us by the SRSA (Swedish Rescue Services Agency) and in collaboration with the Department of Fire Safety Engineering at Lund University.

Please send in your answer before 19 of September 2005.

If you have any questions about the thesis or this questionnaire please don't hesitate to contact us.

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Email: cjb@srv.se

Niclas Christoffersson
Mobile: +46 (0)704539100
Email: nch@srv.se

General

Date: ____________________

Name: ____________________

Address: ____________________

Country: ____________________

Telephone: ____________________

Organization: ____________________

Team Position: ____________________

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Methods

1. **Describe, in brief, the methods /procedures that your USAR teams use when they search for live victims in rubbles.**

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2. **What advantages and disadvantages exist in relation to the types of search methods that your teams use?**

ADVANTAGES:

DISADVANTAGES:

3[16]

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Equipment

3. **Indicate what kind of technical equipment your teams use to detect and locate live victims during USAR operations. If you can, please name the manufacturers of the equipment.**

Equipment		Manufacturer
☐ **Fiber optic detector**		__________
☐ **Thermal imaging detector**		__________
☐ **Ultrasonic detector**		__________
☐ **Biosonar**		__________
☐ **Sound or seismic detectors**		__________
☐ **Infrared goggles**		__________
☐ **Self-reliant robot detector**		__________
☐ **Electric visual detecting device**		__________
☐ **Other:**	__________	__________
☐ **Other:**	__________	__________
☐ **Other:**	__________	__________

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4. **What advantages and disadvantages exist in relation to the types of search equipment that your teams use?**

ADVANTAGES:

DISADVANTAGES:

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Operations

Questions 5 to 13 should be answered for the major USAR operations that your organisation's USAR teams have participated in. You can provide details of up to eight operations. If your organisation and its teams have worked on more major operations than this then please select the eight that you feel differ in outcome and in the methods that were used.

Questions 14 to 17 are open questions. The answers to these questions can contain both internal factors, such as equipment, personnel etc, and external, such as governmental, organizational etc.

If you have any reports in English that contain the specific information requested, then instead of writing the answers after the following questions, you can send us a copy of the report and just refer to it after the relevant question.

If there is any more information, other than that requested, that you think is important, then please write it down on the blank sheet on page 15.

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	OPERATION 1		OPERATION 2		OPERATION 3		OPERATION 4	
Affected country								
Type of disaster								
Date and time of disaster								
Date and time of your team's arrival								
5. How many teams from your organization participated during the operation?								
6. Approximately how many personnel were on each of your teams?								
7. Approximately how many objects/sites did your teams search during the operation?								
8. During the operation did your teams actively search for dead victims?	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No
9. During the operation did your teams search for victims during the hours of darkness?	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No
10. During the operation how many confirmed live victims did your teams detect during daylight and during darkness?		**DETECTED**		**DETECTED**		**DETECTED**		**DETECTED**
	Daylight		Daylight		Daylight		Daylight	
	Darkness		Darkness		Darkness		Darkness	
11. How many confirmed live victims did your teams detect each day after the occurrence of the disaster?		**LIVE VICTIMS**		**LIVE VICTIMS**		**LIVE VICTIMS**		**LIVE VICTIMS**
	First day		First day		First day		First day	
	Second day		Second day		Second day		Second day	
	Third day		Third day		Third day		Third day	
	Fourth day		Fourth day		Fourth day		Fourth day	
	Fifth day and after		Fifth day and after		Fifth day and after		Fifth day and after	

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	Detected with	OPERATION 1 Number of detected	OPERATION 2 Number of detected	OPERATION 3 Number of detected	OPERATION 4 Number of detected
12. How many confirmed live victims did your teams <u>detect</u> with each different piece of equipment or method? *If your team's method or equipment is missing, fill it in after "Other"*	Locals pointed out the victim				
	The victim was visually detected				
	The victim was audibly detected				
	Search dogs				
	Fiber optic detector				
	Thermal imaging detector				
	Ultrasonic detector				
	Biosonar				
	Sound or seismic detectors				
	Infrared goggles				
	Self-reliant robot detector				
	Electric visual detecting device				
	Other:				
	Other:				

	Located with	Number of located	Number of located	Number of located	Number of located
13. How many live victims did your teams <u>locate</u> with each different piece of equipment or method? *If your team's method or equipment is missing, fill it in after "Other"*	Locals pointed out the victim				
	The victim was visual detected				
	The victim was audibly detected				
	Search dogs				
	Fiber optic detector				
	Thermal imaging detector				
	Ultrasonic detector				
	Biosonar				
	Sound or seismic detectors				
	Infrared goggles				
	Self-reliant robot detector				
	Electric visual detecting device				
	Other:				
	Other:				

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	OPERATION 5		OPERATION 6		OPERATION 7		OPERATION 8	
Affected country	----------		----------		----------		----------	
Type of disaster	----------		----------		----------		----------	
Date and time of disaster	----------		----------		----------		----------	
Date and time of your team's arrival	----------		----------		----------		----------	
5. How many teams from your organization participated during the operation?								
6. Approximately how many personnel were on each of your teams?	---------- ----------		---------- ----------		---------- ----------		---------- ----------	
7. Approximately how many objects/sites did your teams search during the operation?	----------		----------		----------		----------	
8. During the operation did your teams actively search for dead victims?	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No
9. During the operation did your teams search for victims during the hours of darkness?	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No	☐ Yes	☐No
10. During the operation how many confirmed live victims did your teams detect during daylight and during darkness?		**DETECTED**		**DETECTED**		**DETECTED**		**DETECTED**
	Daytime		Daytime		Daytime		Daytime	
	Nighttime		Nighttime		Nighttime		Nighttime	
11. How many confirmed live victims did your teams detect each day after the occurrence of the disaster?		**LIVE VICTIMS**		**LIVE VICTIMS**		**LIVE VICTIMS**		**LIVE VICTIMS**
	First day		First day		First day		First day	
	Second day		Second day		Second day		Second day	
	Third day		Third day		Third day		Third day	
	Fourth day		Fourth day		Fourth day		Fourth day	
	Fifth day and after		Fifth day and after		Fifth day and after		Fifth day and after	

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	Detected with	OPERATION 5 Number of detected	OPERATION 6 Number of detected	OPERATION 7 Number of detected	OPERATION 8 Number of detected
12. How many confirmed live victims did your teams detect with each different piece of equipment or method? *If your team's method or equipment is missing, fill it in after "Other"*	Locals pointed out the victim				
	The victim was visually detected				
	The victim was audibly detected				
	Search dogs				
	Fiber optic detector				
	Thermal imaging detector				
	Ultrasonic detector				
	Biosonar				
	Sound or seismic detectors				
	Infrared goggles				
	Self-reliant robot detector				
	Electric visual detecting device				
	Other:				
	Other:				

	Located with	Number of located	Number of located	Number of located	Number of located
13. How many live victims did your teams locate with each different piece of equipment or method? *If your team's method or equipment is missing, fill it in after "Other"*	Locals pointed out the victim				
	The victim was visually detected				
	The victim was audibly detected				
	Search dogs				
	Fiber optic detector				
	Thermal imaging detector				
	Ultrasonic detector				
	Biosonar				
	Sound or seismic detectors				
	Infrared goggles				
	Self-reliant robot detector				
	Electric visual detecting device				
	Other:				
	Other:				

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14. During any of operations mentioned above, were there any particular circumstances or methods that lead to the detection or localization of a live victim?

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15. If any of the operations mentioned above went well, write down the factors that you think contributed to that.

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16. If any of the operations mentioned above <u>did not</u> go well, write down the factors that you think contributed to that.

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17. What can make the search for live victims more effective?

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Thank you very much for completing this questionnaire.
Please send it to:

[redacted]

The thesis will be published in January 2006 and a copy, containing the results, will also bee sent to you then.

Carl-Johan Bäckström & Niclas Christoffersson

SWEDISH RESCUE SERVICES AGENCY