13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 3092

ASSESSMENT OF THE SEARCH AND RESCUE DEMAND FOR INDIVIDUAL BUILDINGS

Christine SCHWEIER[1], Michael MARKUS[2]

SUMMARY

This paper presents two possibilities to assess the **S**earch **a**nd **R**escue (SAR) demand for individual buildings based on aerial detected collapse patterns. On the basis of height measurements with airborne laser scanning, geometrical models of buildings can be generated. Comparing the undamaged pre-event models with those recorded after an earthquake, the location of collapsed buildings and the dimension and characteristic of their damage can be obtained. To interpret the changes, observations and reports of building collapses were analyzed leading to a definition of a damage catalogue including typical damage types of buildings with their respective geometrical characteristics. The required SAR personnel and equipment for each collapsed building depends mainly on the construction and the damage type of the building, the building size, the degree of the collapse and the number of casualties. To detect the qualitative and quantitative influence of these parameters on the SAR demand, after action reports related to SAR activities in collapsed buildings and questionnaires from an international expert survey were analyzed. Furthermore the experience of rescue organizations was taken into consideration. The developed methods use the results of the rapid aerial damage state analysis of the buildings to assess on the one hand the primary demand for SAR resources for collapsed buildings and on the other hand in a first step the casualties and based on this information the demand for SAR personnel.

INTRODUCTION

Strong earthquakes in urban areas cause every year thousands of casualties. The principal cause of death in the most large-scale earthquake disasters is the collapse of buildings (compare Coburn & Spence, 2002 [1]). The survivors in collapsed buildings could often be rescued by fast and efficient measures. But in the aftermath of earthquakes, especially in urban areas, the number and location of collapsed buildings are unknown and it is not clear how many people are affected. In addition, the search and rescue (SAR) resources of the stricken area are often not sufficient to cope with the disaster. For these reasons a fast ascertainment of the needed search and rescue (SAR) personnel and equipment for each individual collapsed

[1]Project Scientist, Institute for Technology and Management in Construction, University of Karlsruhe (TH), Germany. Email: schweier@tmb.uni-karlsruhe.de
[2]Project Scientist, Institute for Technology and Management in Construction, University of Karlsruhe (TH), Germany. Email: markus@tmb.uni-karlsruhe.de

building is helpful for the disaster management in order to allocate the limited SAR resources of the disaster area in an optimal way.

Research in the field of disaster management benefits from the collaboration of different disciplines. In this spirit, the Collaborative Research Center 461 (CRC 461) "Strong Earthquakes: A Challenge for Geosciences and Civil Engineering" at Karlsruhe University was founded in 1996 (see also Wenzel, 1997 [2]). This long-term research project is a multidisciplinary attempt at earthquake damage mitigation, with regional focus on the Vrancea events in Romania. This paper presents work done within the subproject C7 "Novel Rescue and Restoration Technologies" in collaboration with other subprojects of this CRC.

A large number of parameters are influencing the required SAR personnel and equipment for a collapsed building like for example its construction type, its damage pattern, the number of the trapped victims, the climatic conditions etc. The precondition for a fast determination of the required SAR resources is the fast ascertainment of the influencing factors. The described methods to ascertain the needed SAR resources for each individual collapsed building are based on aerial detected collapse patterns. In the following, firstly the concept to rapidly determine the collapse patterns of affected buildings in case of an earthquake disaster is described in brief. Then the damage catalogue used to classify the detected damages is presented. This is followed by an explanation of the investigations carried out to determine the influencing factors for the SAR demand. In the last part, the authors present first results in the assessment of the needed SAR resources.

CONCEPT OF RAPID DAMAGE DETECTION

One of the main deciding factors for the needed SAR resources is the knowledge about the location, the extent and the characteristic of a totally or partially collapsed building. A fast acquisition of such data is as already mentioned essential for a rapid assessment of the needed rescue personnel and equipment. Within the CRC a method based on airborne laserscanning is researched by subproject C5 (compare e.g. Steinle & Vögtle, 2001 [3]) to obtain rapidly information about the damage situation of buildings in affected areas. This method will be briefly described in the following.

Laserscanning and building modeling

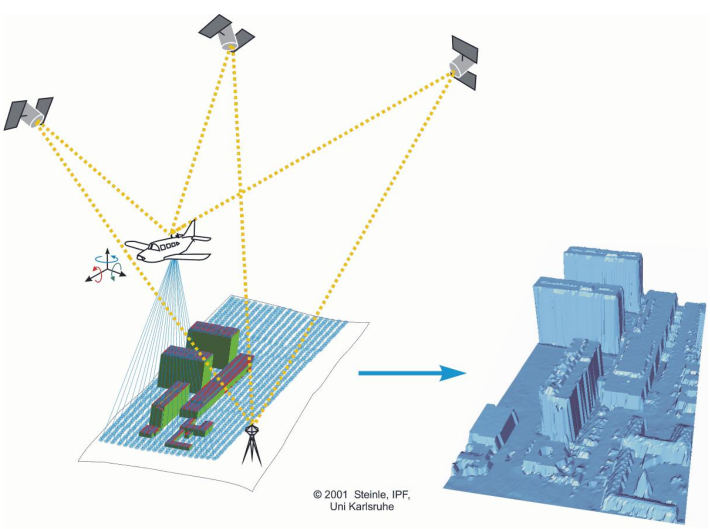


Figure 1: Principle of laserscanning (Steinle, 2001)

Since the early nineties, the laserscanning technology - an active airborne scanning technique - is operational and successfully used for dense three-dimensional point measurements (see e.g. Ackermann, 1999 [4]). This technique allows producing height data sets, e.g. digital surface models (DSM) in an efficient and rapid way. Based on these data three-dimensional vector models of the building can be produced. In this approach, an automatic methodology is used to model the buildings' geometry. The modelling itself is based on the assumption that buildings are complex structures that can be approximated by piece-wise planar regions.

On account of this, planar parts in the DSM are extracted and their interconnections are analyzed to find the geometric primitives of the regarded buildings (faces, lines and points). These can be connected, leading to vector models of the buildings' geometry.

Change detection and damage interpretation

To be able to detect earthquake caused building damages, the buildings' geometry in their intact state must be known. Comparing the geometry of buildings before and after a destructing event, like e.g. an earthquake, it is possible to detect the changes between the two states and to quantify them by using change measures like volume differences, plane orientation change, height change or size alteration. These changes must be further analyzed and interpreted. Modifications at buildings, especially in urban areas, are not necessarily caused by damages. They can also be a result of normal modifications, e.g. by construction activities (see Steinle & Bähr, 2002 [5] for details). The changes identified as not being caused by normal urban modifications are classified in damage types using the previously developed damage catalogue, the concept of which is presented in the following chapter. The classification of the identified changes into damage types is done automatically by comparing the geometrical characteristics of each damage type stored in the damage catalogue with those observed at the modified building (parts) after an earthquake. As they will rarely fit exactly, the most likely damage type of the catalogue will be assigned, but the ratio of concordance will also be given.

DAMAGE CATALOGUE

The purpose of this catalogue is to serve as a basis for classification of different damage types of buildings occurring after earthquakes. Damage types describe in this approach the damage situation of complete buildings. The definition of the damage types is based on the classes suggested by Okada & Takai, 2000 [6]. Their classification was developed for a fast survey of damages by observers walking within the affected areas and it covers only a small number of damage structures. Therefore, his damage type list was adapted and enhanced. The compilation of possible collapse forms was made according to the following criteria:

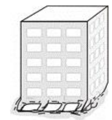
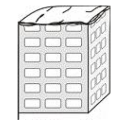
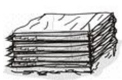
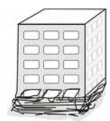
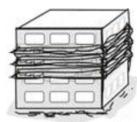
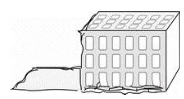
- coverage of all typically occurring damage types at earthquakes
- detectability of the characteristics of the damage types in airborne laserscanning data
- differentiation of damage types that cause different casualty numbers or have different SAR rescue needs

The damage catalogue was set up using various after action and damage reports as well as pictures of damaged buildings, which were collected and analyzed for this purpose. The result is a catalogue (compare table 1) with 10 different damage types and their respective geometrical characteristics that are listed in extracts below:

- Total height difference to initial height
- Volume reduction
- Recognizability of the footprint borders
- Surface structure
- Change of the inclination regarding to the initial situation within the footprint
- Size of the recognizable planes
- Debris structure outside of the footprint
- Size of the debris
- Height difference at the footprint border
- Number of visible walls
- Structure of the roof

The different damage types can unambiguously be characterized by these particulars and in this way determined from the airborne height measurements. To date 1089 pictures of 121 different damaged buildings are included in the damage catalogue database. Additional data were collected for these buildings, for instance the construction types, the social function and the damage patterns.

Table 1: Compilation of the damage types

 1. Inclined plane	 2. Multi layer collapse	 3. Outspread multi layer collapse	 4 a) Pancake collapse, first floor	 4b) Pancake collapse, intermediate story	 4c) Pancake collapse, upper story
 5. Pancake collapse, all stories	 5a) Pancake collapse, several lower stories	 5b) Pancake collapse, intermediate stories	 5c) Pancake collapse, upper stories	 6. Heap of debris on uncollapsed stories	 7a) Heap of debris
 7b) Heap of debris with planes	 7c) Heap of debris with vertical elements	 8. Overturn collapse, separated	 9a) Inclination	 9b) Overturn collapse	 10. Overhanging elements

SEARCH AND RESCUE DEMAND

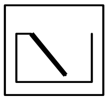
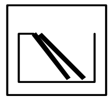
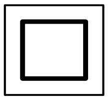
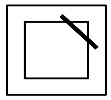
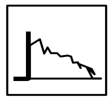
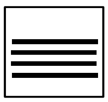
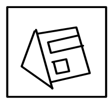
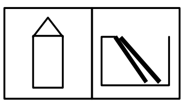
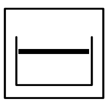
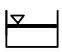
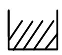
Starting from the presented damage types several investigations were carried out to determine the main influencing factors for the needed SAR resources and to develop a method to ascertain the needed SAR personnel and equipment depending on the damage types.

Analysis of the influencing factors

First, experiences from past rescue operations were collected and analyzed. For this purpose an international expert survey was launched. Questionnaires were sent to organizations that were involved in rescue operations after building collapses (not necessarily caused by earthquakes) requesting them to complete the questionnaire for one collapsed building in order to find the important correlation between building type, damage type and rescue operations. In the questionnaires information was inquired about the event, the building, the building's damage state, the rescue operations, the victims, the used rescue methods, the needed rescue personnel, the used equipment, weather conditions, etc. In the last eight years about 240 questionnaires have been collected, included in the basic knowledge base and evaluated. Using additionally the information stored in the damage catalogue database the relation between damage types, building types and damage patterns was analyzed for the modeling of the SAR demand assessment.

Damage patterns serve for the systematic description of occurred destructions at buildings or building elements. They refer mainly to the destruction forms of certain rooms and locally limited rubble structures. Therefore a complete destroyed building will normally have many different damage patterns.

Table 2: Damage patterns

Symbols	Damage patterns		Symbols
	plane with angular voids	multi layer collapse	
	blocked room	hit room	
	rubble heap/ debris	outside debris debris out of building borders	
	pancake collapse	overturn collapse	
	High rise collapse patterns, first symbol is an additional attribute which can be used with the other symbols		
	infilled room with  fluid,  debris,  multi layer		

The damage patterns are used by German rescue teams. Table 2 shows the damage patterns, which are a further development of the initial damage patterns made in collaboration with the THW (**T**echnisches **H**ilfs**w**erk - governmental disaster relief organization of Germany). Further details can be found in [7].

Due to many years of experience with these damage patterns, the position of trapped victims, their survival chances and the related rescue works can be inferred. Knowing the typical occurring damage patterns for each damage type, the search and rescue needs can be deduced.

Certain rescue operations, with particular accurate and well completed questionnaires, were examined more in detail concerning the used methods, equipment and procedures as well as personnel and time requirements.

In a second survey the kind and number of the vehicles (including equipment) and the personnel that are sent as standard by the control stations of the fire brigades to a collapsed building in Germany were evaluated. This standard compilation can be modified from the fire brigade controller according to his experience and the present situation. Building collapses in Germany are in the majority of cases the result of gas explosions, but the damage types are partially comparable with those caused by earthquakes. It was asked for the different compilations of SAR resources in cases of building collapses with and without trapped persons.

The studies conducted show among others, that

- Different damage types require different SAR resources.
- The needed *SAR resources as a whole* are just partially depending on the number of the trapped victims, because rarely the exact number of victims is known and for this reason the whole damage site must be worked. But at large building collapses with a large number of trapped victims, the required *number of rescue personnel* in particular is depending on the probable number of trapped persons.
- The equipment of German rescue organizations and also of international search and rescue teams are, according to their own statements, in the most cases sufficient to cope with the respective tasks. For this reason no further studies were carried out in this field.

Assessment of the demand for SAR resources per damage type

Based on these conclusions, and the investigations carried out a basic demand for resources for all damage types (compare table 3) and a complementary demand for each damage type was developed, which take in consideration the particular needs of the respective damaged structures. Table 4 shows as example the complementary demand for the damage type 3 - outspread multi layer collapse. In these compilations only the demand for the technical search and rescue is included. Medical needs or the demand for police forces for example are excluded. The proposed needs for SAR resources are related to a predefined damage situation and are based on the assumption of sufficient resources in the disaster area. The defined standard case is the collapse of a residential used building with several stories and different possible construction types. The building is characterized by only one collapse type and the occupancy at the time of the destroying event is about 20 persons.

Table 3: Basic demand for technical SAR resources

Number	Vehicles	Crew	Notes
Fire Brigade:			
2	ELW1 (operation leading vehicle)	1/1	
3	KdW (commando vehicle)	1/1	
4	HLF (fire engine)	1/5	
2	DLK (turntable-ladder vehicle)	1/1	
1	KW (crane car)	1/1	
2	AB-Rüst (swap body for scaffolding demand)	1/1	on chassis; also possible swap body-‘crane’, -‘construction’, - ‘height rescue’, - ‘trough’
1	NEF (emergency doctor’s car)	1/1	for self-protection
1	RTW (ambulance)	1/1	for self-protection
1	ELW2 (operation leading vehicle)	1/2	management component (possibly from auxiliary fire brigade)
Auxiliary fire brigade:			
3	LF (fire crew vehicle)	1/8	and RW (emergency tender) 1 and 2, if available
THW (governmental disaster relief organization of Germany)			
1	MTW (personnel carrier)	2/2	management component
2	GKW (civil defense equipment vehicle)	3/9	two rescue units
1	MTW (personnel carrier)	3/9	section ‘search’
1	BRmG (special wheel loader)	3/9	section ‘clearing’
1	LKW (truck)		
Relief organizations			
1	MTW (personnel carrier)	1/6	search canine unit
Sum:	27 vehicles	137 persons (47 fire brigade, 4 fire brigade-ambulance service, 27 auxiliary fire brigade, 52 THW, 7 relief organizations)	

Table 4: Complementary SAR demand for damage type 3 - outspread multi layer collapse

Demand:	Basic demand, complemented for outspread multi layer collapse
Demand on additional personnel:	18 persons from the fire brigade, 9 persons from auxiliary fire brigade, 28 persons from THW, 4 persons from relief organizations
Demand on additional equipment:	2 HLF (fire engine), 1 DLK (turntable-ladder vehicle), 1 AB-Rüst (swap body for scaffolding demand) from the fire brigade
	1 LF (fire crew vehicle) from auxiliary fire brigade
	1 MTW (personnel carrier), 2 GKW (civil defense equipment vehicle) from THW
	1 MTW (personnel carrier) from relief organizations
	1 truck-mounted crane
	1 raised platform (for observation)

The suggested SAR personnel and equipment for each damage type to dispatch, meet in any cases the requirements in the first phases of the operation at a disaster site, which is in the order of this standard case.

As each collapse is unique, a reduction or an enlargement of these SAR resources will probably be necessary, first by the controller and later by the officer-in-charge, when sufficient overview about the situation is available.

As the assumption of sufficient resources is rarely given after catastrophic events, the presented chain of resources must be further developed and optimized for disaster cases. It must be analyzed which reduction of these resources degrades the success of the rescue operations the least.

Assessment of the needed rescue personnel

Furthermore, a model for the estimation of the needed rescue personnel was developed in dependence on the expected number of trapped persons, for each collapsed building (compare figure 2). This model is based on the determination method for rescue personnel of the German civil protection [8]. With knowledge of the damage types, a more reliable estimation of the number of trapped persons is possible, leading to a more exact assessment of the needed rescue personnel.

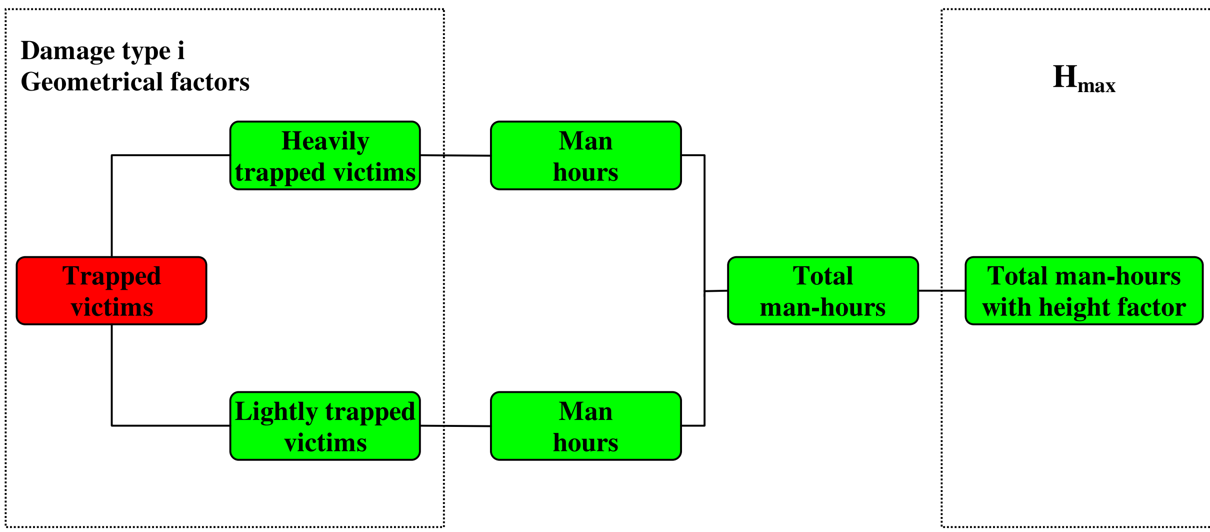
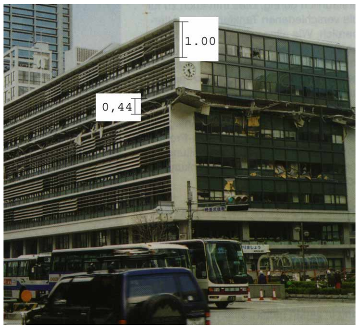


Figure 2: Flow diagram of the estimation model for the rescue personnel demand

This geometry-based casualty estimation model, the concept of which will be published soon, is based on the assumption, that the number of trapped victims is primarily dependent on the indoor space reduction. The total number of the casualties and the number of the trapped part of the victims are computed thereby for each individual collapsed building. For this purpose, by evaluation of the above mentioned damage catalogue database, typical *volume reduction factors per story* (γ) were developed for the different damage types taking also into consideration the social function of the buildings. Table 5 shows the developed range of γ for the different damage types and a simple example for the proceeding at the evaluation of the pictures.

As this factor is correlated to the degree of the entombment, it is also used to divide the number of the trapped victims, that was previously determined by the casualty estimation model, in heavily and lightly trapped victims. The higher γ is the bigger is the rate of heavily trapped victims, whose rescue is more difficult due to the confined space situations or conditions that can be hardly penetrated. Starting from the number of heavily and lightly trapped victims, the required man-hours can be computed. In table 6 the man-hours per trapped victim are given depending on the damage type and the degree of entombment.

Table 5: Specific volume reduction factor



γ_i ascertainment
$\gamma_i = 1-0.44=0.56$

City Hall Kobe
(original picture [9], page 7)

Damage type i	Range of γ_i		Explanatory notes
	Commercial/ Educational function	Residential function	
1	0,4-0,6	0,4-0,6	
2	0,6-0,7	0,7-0,75	$\gamma_2 > \gamma_1$: major domino effect
3	0,6-0,75	0,6-0,75	
4	0,5-0,7	0,65-0,75	
5	0,7	0,75	$\gamma_5 > \gamma_{5a,b,c}$: major domino effect
5a,b,c	0,55-0,7	0,7-0,75	$\gamma_{5a,b,c} > \gamma_4$: major domino effect
6	0,65-0,75	0,7-0,75	
7a,b	0,65-0,75	0,7-0,75	
7c	0,6-0,7	0,6-0,7	γ7c < γ7b,c: big debris pieces wedge at the walls: more voids
8	0,9	0,9	mathematical value
9a	0-0,6	0-0,6	0 when ground liquefaction, otherwise like γ_1
9b	-	-	no volume reduction

Table 6: Man-hours per trapped victim

Damage type	Damage degree	Degree of entombment	Percentage of heavily or lightly trapped victims	ε_i (man-hours / trapped victim)
1	Partial collapse	Heavy	γ_i	8
		Light	$1-\gamma_i$	4
2	Total collapse	Heavy	γ_i	20
		Light	$1-\gamma_i$	8
3	Total collapse	Heavy	γ_i	20
		Light	$1-\gamma_i$	8
4	Partial collapse	Heavy	γ_i	8
		Light	$1-\gamma_i$	4
5	Total collapse	Heavy	γ_i	20
		Light	$1-\gamma_i$	8
6	Total collapse if $G_c > 1$, otherwise partial collapse*	Heavy	γ_i	20
		Light	$1-\gamma_i$	8
7	Total collapse if $G_c > 1$, otherwise partial collapse*	Heavy	γ_i	20
		Light	$1-\gamma_i$	8
8	Partial collapse if V_{Red}<25% and G_c<2, otherwise total collapse*	Heavy	0,35	8
		Light	0,65	4
9a	Partial collapse	Heavy	γ_i	8
		Light	$1-\gamma_i$	4
9b	Partial collapse if V_{Red}<25%, otherwise total collapse *	Heavy	0,35	8
		Light	0,65	4
10	Hit building	Heavy	-	2
		Light	-	0,4

*G_c = Number of the collapsed stories of a damaged building - calculated by evaluation of the laserscanning data
V_{Red} = Volume reduction of the building - calculated by evaluation of the laserscanning data

The so calculated man-hours must be increased for rescue sites with damages high above ground. In the following table, the increasing factors depending on H_{max} are compiled. H_{max} describes the average damage height of a building and can be calculated by evaluation of the airborne laserscanning data.

Table 7: Height categories and increasing factor $\delta_{H\,max}$

Height category	Height range of H_{max} [m]	Factor δ_{Hmax} [-]
Height category 1	0-8	1,0
Height category 2	8-23	1,5
Height category 3	23-55	2,0
Height category 4	55-200	>5

Since in case of disaster there is often a lack of professional rescue personnel, other human resources should be taken into consideration for the rescue of the trapped persons. The possible groups of people that could support the rescue works are classified in the following and their effectiveness compared with the professional rescue personnel is given.

- Category 1: professional rescue personnel from civil protection, fire brigades, military. The man-hours are calculated for this category, i.e. the effectiveness is 100 %.
- Category 2: auxiliary fire brigade, military sappers, special construction companies. These forces have an effectiveness compared with the forces of category 1 of 75%.
- Category 3: construction companies, craftsmen, police, military. These forces have an effectiveness compared with the forces of category 1 of 60%.
- Category 4: civilians not included in the categories above. These forces have an effectiveness compared with the forces of category 1 of 33%.

Depending on the damage type just a certain part of the rescue works can be taken over by the non-professional forces. The maximal possible relief of the professional forces is indicated in the following table.

Table 8: Percentage of the category 1 forces that can be replaced by other forces

Damage type	Forces of category 2 [%]	Forces of category 3 [%]	Forces of category 4 [%]
1	100	50	40
2	95	40	30
3	95	40	30
4	95	40	30
5	85	30	20
6	95	60	50
7a,c	100	90	80
7b	95	30	20
8	100	60	50
9a	95	50	40
9b	100	60	50
10	100	100	100

The computed man-hours are referred to a fully equipped and trained rescue team with all necessary functionalities like management, rescue, safety, etc. On account of this they must be optimized to the operating time and the rescue team size under inclusion of the possibility to replace the professional forces by other of the above mentioned forces that are available (compare calculation example in table 9).

Table 9: Calculation example for damage type 3 - outspread multi layer collapse

	Input	**Value**	**Source**
	Trapped victims V_T	6,86	Casualty estimation model
	H_{max} [m]	4,73	Evaluation of airborne laserscanning data
	γ_i [-]	0,7	Model parameter, compare Table 5 (residential function)
	Damage degree	Total collapse	Evaluation of airborne laserscanning data
	Effectiveness of category 4 forces e_4 [%]	33	Model parameter
	Unit size u_S [person]	35	
Calculation		**Value**	**Equation**
Heavily trapped victims V_{HT}		4,80 ~ 5	$V_{HT} = \gamma_i * V_T$
Lightly trapped victims V_{LT}		2,06 ~ 2	$V_{LT} = (1-\gamma_i) * V_T$
Man-hours for V_{HT}, Mah_H [Mh]		100	$Mah_H = \varepsilon_i * V_{HT}$
Man-hours for V_{LT}, Mah_L [Mh]		16	$Mah_L = \varepsilon_i * V_{LT}$
Total man-hours Mah [Mh]		116	$Mah = Mah_H + Mah_L$
Total man-hours with height factor Mah_{Tot} [Mh]		116	$Mah_{Tot} = Mah * \delta_{Hmax}$
Number of the required units U_R [unit]		3,3	$U_R = Mah_{Tot} / u_S$
Possible Decision		**Value**	**Equation**
Number of rescue units (chosen) U_C [unit]		3	
Rest: Forces of category 4 F_4 [person]		33	$F_4 = (1/e_4) * (Mah_{Tot} - (U_C * u_S))$

Disaster Management Tool

The presented methods to assess the search and rescue demand for individual buildings are to be integrated in the so called Disaster Management Tool (DMT) to make them applicable. The DMT is a software system supporting decision makers, surveillance and intervention teams during disaster response. It is developed within the Collaborative Research Center (CRC) 461"Strong Earthquakes" based on the results of its engineering research projects. The DMT is designed for earthquake disasters in Bucharest as a test case, but planned to be adaptable to urban areas in industrializing countries with various disaster types. For more details compare Markus et. al. [10].

CONCLUSIONS AND FUTURE WORK

This paper presents two different approaches to assess the needed search and rescue personnel and equipment based on the damage types of the collapsed buildings. The first is a compilation of a primary demand for SAR resources for each damage type. The second approach is a method to assess the needed SAR personnel depending on the damage type and the estimated number of trapped victims.

Thereby, the damage states of the buildings after destructive events are determined by evaluation of laserscanning data. To support this evaluation process, a damage catalogue including typical occurring damage types was developed. The appending damage catalogue database will be enlarged to distinguish more precisely the geometrical characteristics of the different damage types and to advance in this way the damage detection process.

The compilation of the primary demand for SAR resources is based on the assumption of sufficient resources in the stricken area. As this situation is rarely given, the developed chain of resources will be adapted to the requirements after catastrophic events with a lot of collapsed buildings. Furthermore this compilation will be enlarged to include also the demand for medical personnel and equipment at the rescue site.

Both approaches to assess SAR resources demand will be included in an integrated Disaster Management Tool to make them applicable for pre and post event management tasks.

ACKNOWLEDGEMENTS

The research presented was done within the subproject C7 of the Collaborative Research Centre (CRC) 461 'Strong Earthquakes: A Challenge for Geosciences and Civil Engineering' (http://www-sfb461.physik.uni-karlsruhe.de). The CRC 461 is funded by the Deutsche Forschungsgemeinschaft (German Research Foundation) and supported by the State of Baden-Württemberg and the University of Karlsruhe. The authors would like to take the opportunity and thank for the offered possibilities.

REFERENCES

1. Coburn A, Spence R. “Earthquake Protection”. Second Edition, John Wiley & Sons, Ltd. 2002.
2. Wenzel F. “A Challenge for Geosciences and Civil Engineering – A New Collaborative Research Center in Germany”. Seismological Research Letters 1997; Vol. 68, Iss. 3: p. 438-443.
3. Steinle E, and Vögtle T. “Automated extraction and reconstruction of buildings in laserscanning data for disaster management”. Proceedings of the Workshop Monte Verita, Switzerland, 10-15 June 2001, Baltsavias EP, Gruen A, and Van Gool L, Editors. Automatic Extraction of Man-Made Objects from Aerial and Space Images (III). Balkema (Swets & Zeitlinger), Lisse, The Netherlands, 2001: p. 309 - 318.
4. Ackermann F. “Airborne laser scanning – present status and future expectations”. ISPRS (International Society for Photogrammetry and Remote Sensing), Journal of Photogrammetry and Remote Sensing 1999; Vol. 54 (1999): 64 - 67.
5. Steinle E, and Bähr HP. „Detectability of urban changes from airborne laserscanning data”. Navalgund RR, Nayak SR, Sudarshana R, Nagaraja R, Ravindran S, Editors. Resource and environmental monitoring. ISPRS commission VII symposium, Hyderabad, India, December 2002.
6. Okada S, Takai N. “Classifications of Structural Types and Damage Patterns of Buildings for Earthquake Field Investigation”. Twelfth World Conference on Earthquake Engineering, 705/4/A, Balkema, Rotterdam, 2000.
7. Gehbauer F, Hirschberger S, Markus M. „Methoden der Bergung Verschütteter aus zerstörten Gebäuden“. Zivilschutzforschung, Neue Folge Band 46, ISSN 0343-5164, Bundesverwaltungsamt, Zentralstelle für Zivilschutz, Bonn, 2002.
8. Bundesamt für Zivilschutz. Katastrophenschutzleitfaden (KatS-LA) 261: „Der Bergungseinsatz bei Gebäudeschäden“, Bonn, 1986.
9. Smolka A. „Das „Große Hanshin-Erdbeben“ vom 17.Januar 1995 in Kobe Japan“. Schadenspiegel 1995, 38(1): p. 3-11.
10. Markus M, Fiedrich F, Leebmann J, Schweier C, Steinle E. “Concept for an integrated Disaster Management Tool”. Thirteenth World Conference on Earthquake Engineering, Paper No. 3094, Vancouver, Canada, 2004.