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Wien, September 2018 Sandra Heinemann

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List of Abbreviations

AECA	Adaptive Epsilon-Constraint Algorithm
AFDRU	Austrian Forces Disaster Relief Unit
CBRN	Chemical-Biological-Radioactive-Nuclear
CIMIC	Civil-Military Cooperation
CP	Compromise Programming
DC	Distribution Center
DEA	Data Envelopment Analysis
EA	Evolutionary Algorithm
ECHO	European Civil Protection and Humanitarian Aid Operations
ES	Emergency Shelter
GA	Genetic Algorithm
GP	Goal Programming
GSMOGA	Greegy-Search-based Multi-Objective Genetic Algorithm
HADS	Humanitarian Aid Distribution System
IDA	International Development Association
LGP	Lexicographic Goal Programming
LP	Linear Programming
MA	Magistratsabteilung
MC	Medical Center
MCTP	Maximal Covering Tour Problem
MIP	Mixed Integer Problem
MILP	Mixed Integer Linear Programming
MOEA	Multi-Objective Evolutionary Algorithm
MOP	Multi-Objective Optimization Problem
NGO	Non-Governmental Organization
NSDE	Non-dominated Sorting Differential Evolution
NSGA	Nondominated Sorting Genetic Algorithm
NSGA-II	Nondominated Sorting Genetic Algorithm-II
ObstdG	Oberst des Generalstabsdienstes
PDDRLS	Post-Disaster Debris Reverse Logistics System

RLC	Relief Logistic Center
TLGP	Two-step Logarithmic Goal Programming
UN	United Nations
UNDP	United Nations Development Program
VNS	Variable Neighborhood Search
VRP	Vehicle Routing Problem
W-KKG	Wiener Katastrophenhilfe- und Krisenmanagementgesetz
WLRP	Warehouse Location-Routing Problem

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1. Introduction

"One of the most important tools to make the best use of existing resources and to enable fast relief even under aggravated circumstances, is logistics." (Golden, et al., 2014, p. 4)

The present master's thesis deals with multi-objective optimization problems under extremely harsh conditions, i.e. in emergency situations. Since in the last years and decades the occurrence of disasters has steadily increased, optimization related to this kind of problem has gained in importance and will gain in importance in the future as well. These mathematical problems are directly connected with saving peoples' lives and therefore, they deserve special consideration in literature and real life.

In this thesis, relevant literature on this topic is reviewed. The literature review *Multicriteria optimization in humanitarian aid* by Gutjahr and Nolz (Gutjahr & Nolz, 2016) is taken as a basis and eleven out of twenty-seven shortly reviewed articles by Gutjahr and Nolz considering deterministic multicriteria optimization as well as two out of fourteen articles covering multicriteria optimization under uncertainty are reviewed in greater detail in the present thesis. Here, a good mix of solution method, i.e. exactly or heuristically, as well as the underlying decision model is achieved. Gutjahr and Nolz (2016) ordered their articles depending on the phase of disaster management. In this literature review, the articles are categorized by their objectives.

The thesis starts with an introduction to multi-objective optimization, the underlying mathematical problem formulation and objectives this kind of problems deal with. Afterwards, the most common solution methods are indicated and described in detail. In the third chapter, the focus lies on humanitarian logistics and the four phases of disaster management, i.e. mitigation, preparedness, response and recovery. Following, the most common objectives related to disaster management are accurately described. The main part of this thesis is dedicated to multi-objective optimization in disaster management and different articles are reviewed and structured in treated objectives.

In order to get some insights in practical experience, two expert interviews with Ing. Mag. Klaus T. Jäger, ObstdG, Austrian Armed Forces and Ing. Alexander Gratz, BA, head of disaster emergency service at the Vienna Red Cross were conducted. These two organizations were chosen due to the fact that there can't be more difference, since one is a governmental organization and the other one is a non-governmental organization. One of the most interesting parts of these two interviews is that for one expert, costs do not play any role in their operations and for the other expert, costs play a crucial role and influence the decision-making processes massive. Since both interview partners independently mentioned the issue of blackout and the imminent danger also for developed countries like Austria, a little excursus is dedicated to this important subject.

2. Multi-objective optimization

Multi-objective optimization is the optimization of conflicting objectives. It differs from single-objective optimization, since in the case of a single objective, one aims to find one best solution, usually the global minimum or maximum of an optimization problem, whereas in a multi-objective optimization problem (MOP), a single best solution usually does not exist due to considering more than one objective at the same time. In multi-objective optimization, as the name implies, more than one objective must be optimized. This adds complexity to the problem and results in a trade-off between objectives, since a single best solution is unlikely to be found (Srinivas & Deb, 1995). In real-world-problems, people want to optimize more than one factor at the same time. They want, for instance, to pay the minimum to transport their products yet have those products arrive as quickly as possible to customers. These objectives are often contradictive and, therefore, a compromise is needed. In the following chapter, the mathematical problem formulation of MOPs, most common objectives as well as solution methods are presented.

2.1. Mathematical problem formulation

Caramia and Dell'Olmo (2008) define a MOP as follows:

$$(\text{MOP}) = \begin{cases} \min\left(f_1(\mathrm{x}), f_2(\mathrm{x}), \dots, f_n(\mathrm{x})\right) \\ \mathrm{x} \in S; \end{cases}$$

with $n > 1$ as number of objectives. As this is a formulation of a MOP, at least two objectives are required. Furthermore, $x = (x_1, x_2, \dots, x_n)$ denotes the decision variable vector and S the set of constraints. Since at least two competing objective functions do not provide a unique optimal solution, a set of solutions is generated. This set of solutions is the so-called Pareto-optimal set, where each solution is a trade-off between all objectives and one component cannot be improved without deteriorating the other one at the same time. In other words, a vector $x^* \in S$ is Pareto optimal if there is no other vector $x \in S$ with a higher value for any objective function or if all other vectors have the same value for all objective functions. A point x^* is called weak Pareto optimal if there is no $x \in S$ such that $f_i(x) < f_i(x^*)$ for all $i \in \{1,\dots,n\}$ and strict Pareto optimal if there is no $x \in S$ such that $f_i(x) \leq f_i(x^*)$ for all $i \in \{1,\dots,n\}$ with minimum one strict inequality (Abounacer, et al., 2014).

A solution is determined as Pareto-optimal if and only if there is no other existing solution that is at least as good as x in all objectives and additionally better than x in minimum one objective. Pareto-front is the set of image points composed of all Pareto-optimal solutions. Pareto-optimal solution, i.e. nondominated solutions are optimal solutions to a MOP.

2.2. Objectives

Jozefowiez, et al. (2007) classify possible types of most common objectives for a MOP in objectives related to tour, node activity and resources. These categories and their objectives are described in more detail in the following chapter.

The first objective in the category tour is cost, which can be travel distance, needed time or the number of visited customers. In many optimization problems, costs correspond to arc routing costs. Nevertheless, there exist other motivations for minimizing travel distance with respect to costs, i.e. choosing the shortest route to prevent damaging transported products. Costs can also be expressed as opening costs for facilities plus tour length for picking up and delivering products. Whereas the objective of minimizing costs is an economic one, the second objective regarding the category of tour tries to minimize makespan – corresponding to the length of the longest tour – and therefore is an environmental criterion. A practical example would be trash collection, where the procedure must be finished as quickly as possible, because workers have to sort trash after picking it up. The third objective considers balance and should eliminate inequalities. For defining the objective of balance, the workload of a complete route has to be determined with all components such as route length, number of visited customers, needed time or how many goods are delivered. An example is the transportation of people who are mentally handicapped. Here, the optimization model tries to demonstrate equity when it comes to traveling time and the time people have to spend in the vehicle. Another example is minimizing the sum of the differences between the smallest workload and the workload of each tour, where the workload is defined as needed travel time plus needed time for loading and unloading the truck. Other authors also add waiting time to travel time and time for loading and unloading for defining the whole workload of a complete route. A specific objective related to tour is for instance a profit value connected with each node. On the route, not every node must be visited and, therefore, the objective is to maximize profit and simultaneously minimize the total tour length (Jozefowiez, et al., 2007).

The second category, i.e. objectives dealing with node activity, primarily address time windows in which either minimization of violated constraints and/or waiting time of either customers or drivers is intended. Also, the average accessibility objective belongs to this category, in which the average distance people have to walk to reach a specific point has to be minimized (Jozefowiez, et al., 2007). This objective can be compared with the notion of coverage, an important objective in the context of disaster management. One possible objective is to select nodes with the result of maximum percentage of covered people in order to supply relief goods in a fair way.

The third category subsumes objectives considering resources, and these resources are usually vehicles and goods. To use as few vehicles as possible for a tour is again an economic criterion, because less monetary investment is required. There exist studies considering Vehicle Routing Problems (VRP) with time windows that minimize number of trucks and then for the computed number, route length is minimized. Others treat numbers of vehicles and route length equally (Jozefowiez, et al., 2007).

2.3. Solution methods

In the following chapter, the most common solution methods for MOPs are classified and described. MOPs can be solved either with an exact method or heuristically with the difference that exact methods generate the complete Pareto front and heuristic methods provide solutions that are close to Pareto-optimal solutions but with no assurance that these solutions are Pareto-optimal (Abounacer, et al., 2014). In real-life problems, decision makers often do not have all needed information to formulate a complete mathematical problem. In such situations, an approximation method is useful to see if an exact method is needed and to become acquainted with the knowledge of more and important information to improve the formulation of the problem (Caramia & Dell'Olmo, 2008).

2.3.1. Scalarization Technique

One method to solve MOPs is the Scalarization Technique, also known as the weighted-sum method. This is a method which scalarizes the set of multiple objectives into one single objective function by multiplying each objective with a weight the user can determine individually, depending on the relative importance of every single objective. The result is a new optimization problem with only one single objective function. For convex problems, it is proved that the solution of the single objective problem is also an efficient solution for the MOP, i.e. it belongs to the Pareto-optimal solution set. This method is a very simple and fast one, since solutions are not examined simultaneously due to the transformation into a single objective problem. A potential drawback is the simple thought that two different individually-set weight vectors lead to two different solutions. Furthermore, if a mixed optimization problem has to be solved, all objectives have to be converted into the same type, either a maximum or a minimum optimization problem (Caramia & Dell'Olmo, 2008). Although this is a simple method with less computational effort than other methods, Tricoire et al. (2012) criticize that in disaster relief management, the decisions of those responsible are primarily between monetary and humanitarian objectives. Therefore, it is difficult to define weights for the scalarization technique, because in this sensitive issue, it means defining a weight for the monetary value of a human life. That is why, in their paper, the authors use a solution method based on the epsilon-constraint method (Tricoire, et al., 2012).

2.3.2. Epsilon-constraint Method

Another solution method is the epsilon-constraint or ε-constraint method, in which only one objective is kept while those remaining are restricted within user-specified target values, i.e. an upper bound vector is created, leading to the following mathematical problem if objective 2 is chosen to be minimized:

$$\min f_2(x)$$
$$f_i(x) \leq \varepsilon_i, \ \forall i \in \{1, \ldots, n\} \setminus \{2\}$$
$$x \in S$$

As a consequence, different values of ε create different Pareto-optimal solutions. The method can be used for convex as well as for non-convex MOPs. A drawback is that the solution strongly depends on the appropriate selection of the ε-vector. This vector has to be chosen in a way that it lies between the minimum and maximum value of each objective function. If the number of objectives is greater than two, the method is not as efficient, and it requires more information from the user (Caramia & Dell'Olmo, 2008).

2.3.3. Goal programming and Compromise Programming

Goal programming (GP) is the approach to achieve specific goal values as exactly as possible. For every single objective, desired target values are determined and the solution with the most minimal deviation from all goal values is the best. The following equations show a simple example with target values v_i:

$$f_1(x) \geq v_1$$

$$f_2(x) = v_2$$

$$f_3(x) \leq v_3$$

$$x \in S$$

As can be seen, the goal is not to minimize or maximize objective function values, but to reach specific values for v_i and to get a solution that is as close as possible (Caramia & Dell'Olmo, 2008).

According to Romero, et al. (1998), GP and compromise programming (CP) are highly related to each other, since both are multi-criteria decision-making problems with the use of distance function methods, i.e. the goal of minimizing the distance between a certain point and the actual achievement of each objective function. The difference is that, in GP, this point refers to set targets which can be reached or not. In CP, this point is an ideal point equal to the optimal value of each objective. Although in literature, these methodologies are presented as separate, most CP applications can be restated as GP models (Romero, et al., 1998). CP considers each objective on its own. The resulting reformulated single objective takes the normalized difference between each objective and its corresponding optimal value, sums up these differences for all objectives and tries to minimize this value. This resulting single-objective optimization problem can subsequently be solved (Bozorgi-Amiri, et al., 2013).

2.3.4. Genetic Algorithm

Genetic algorithms (GA) are one of the four main families of evolutionary algorithms (EA), consisting of GA, evolutionary strategies, evolutionary programming and genetic programming (Alba & Dorronsoro, 2008). EAs are inspired by natural search and selection processes and a research field used for searching optimal values in complex multi-optimization problems (Bäck, 1996). Such techniques are based on population, following the rule of survival of the fittest, since some individuals have better genetic material than others; as such, they have better chances to survive, evolve and generate offspring and, as a consequence, create a new pool of genes. Offspring is formed from the genetic information of two parental individuals, and this process is referred to as *recombination* or *crossover* (Alba & Dorronsoro, 2008). An algorithm initializes a starting population that tries to reach better search regions by recombination, mutation and selection. Then, a fitness function searches for chromosomes with higher quality values to reproduce more often. This entire process of recombination and mutation repeats again and again and slightly changes parental information in order to produce their offspring (Bäck, 1996).

The pseudo-code of an EA reads as follows (Alba & Dorronsoro, 2008):

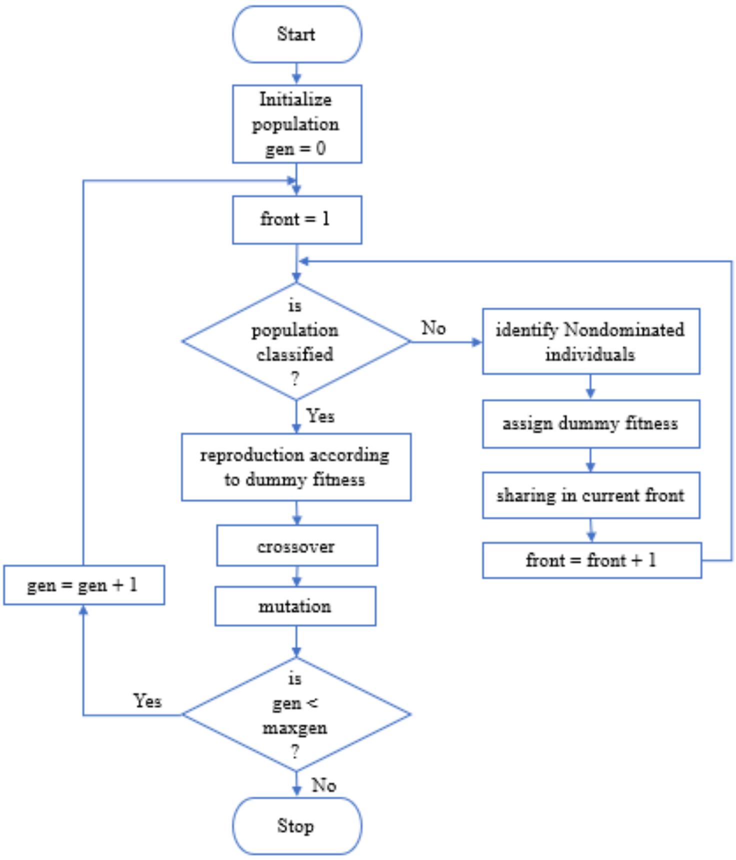
```
P ← GenerateInitialPopulation();
Evaluate(P);
while !StopCondition() do
    P' ← SelectParents(P);
    P' ← ApplyVariationOperators(P');
    Evaluate(P');
    P ← SelectNewPopulation(P,P');
end while
Result: The best solution found
```

Generally, randomly-created individuals generate the initial population in the first step. In the second step, each individual is evaluated via a fitness function, before the while loop starts the process of reproduction consisting of selecting parents, recombining them, mutating of offspring and evaluating them again. In the algorithm, the new population is denoted with P' and is used with the current population P to get individuals for the next generation. The result is the best-found solution EA. Regarding the used population for producing the next generation, two different variants are applicable. Denoting μ as quantity of individuals in P and λ as quantity of individuals in P', (μ, λ)-EA and ($\mu + \lambda$)-EA are possible. The difference is that the former considers only the offspring population while the latter considers both, parental as well as offspring population. In (μ, λ)-EA there is the possibility of losing the currently best solution from the population, whereas in ($\mu + \lambda$)-EA this cannot occur (Alba & Dorronsoro, 2008). The algorithm usually uses four different operators, i.e. selection, crossover, mutation and survival operator. Parents are chosen by selection operator, while crossover and mutation operations slightly change the genetic information of selected parents to create offspring. As the name implies, survival operator searches for the fittest chromosomes and selects those to survive and become the next generation (Esmaeili & Barzinpour, 2014). Different operators are described in more detail when GA is used as a solution method in an article that is reviews in course of this thesis.

2.3.5. Nondominated Sorting Genetic Algorithm – NSGA

With Nondominated Sorting Genetic Algorithm (NSGA), a system of sorting and ranking is used to enhance good nondominated points and a niche method aims to keep subpopulation of these points. Its only difference in comparison with normal GA is the selection operator while crossover as well as mutation operators are the same as for GAs. This algorithm finds multiple solutions that are Pareto-optimal and therefore are very helpful for decision makers. According to Srinivas & Deb (1995), the flow chart of a NSGA looks as follows:

Figure 1: Flow chart NSGA



Own illustration based on (Srinivas & Deb, 1995)

As can be seen in Figure 1, the algorithm is similar to that of a simple GA with the exception of two points: the classification of nondominated fronts and the operation of sharing. For building the first front, each solution is compared to every other solution in the population and a ranking with respect to nondominated points is generated. In a next step, a dummy fitness of high value is assigned, and the same value is valid for all nondominated individuals so that they have an equal potential for reproduction. Then, these individuals are shared with the dummy fitness values. Therefore, two individuals in the same front are taken and a sharing function value is calculated by dividing the dummy fitness value by its niche count, i.e. a quantity proportional to the number of individuals. This parameter is chosen by the decision maker and calculates the proximity measure of two solutions in the same population. In a next step, these individuals are temporarily discounted so that the process can be repeated, and the remaining population can be used to identify the second nondominated front. This is done by using a dummy fitness value that is lower than the minimum shared dummy fitness of the previous front. This process stops if the total population is classified into various fronts. As Figure X shows further on, reproduction happens according to the dummy fitness value. The fact that the first front reproduces more often since individuals have the highest dummy fitness value leads to a rapid convergence towards regions that are nondominated. Also, the sharing function helps spread it over the nondominated region. Crossover and mutation operators stay as in usual GAs (Srinivas & Deb, 1995).

2.3.6. NSGA-II

Deb, et al. (2002) present a nondominated sorting-based Multi-Objective Evolutionary Algorithm (MOEA) called Nondominated Sorting Genetic Algorithm II (NSGA-II) with the three goals of reducing computational complexity, creating an elitism approach for speeding up the GA performance and obviate losing already created good solutions as well as specifying a sharing parameter. The complexity of NSGA is $O(MN^3)$, with M as number of objectives and N as size of population. The highest degree of complexity arises if there are N fronts with only one solution each. Main reason for the high complexity is that every generation must go through the nondominated sorting procedure. That's why Deb, et al. (2002) come up with a fast nondominated sorting approach with a reduced complexity of $O(MN^2)$. This algorithm starts with looking at one solution and defining the number of solutions that are dominated – also called domination count – and the set of solutions that dominate this solution. This is done with every solution and thus has an overall computational effort of $O(MN^2)$. In a next step, for all solutions with a domination count of zero, every member in the set the solution dominates is visited and its domination count is reduced by one. If then a solution results in a domination count of zero, it belongs to the second front. By doing this with every solution, several nondominated fronts with all members are generated (Deb, et al., 2002).

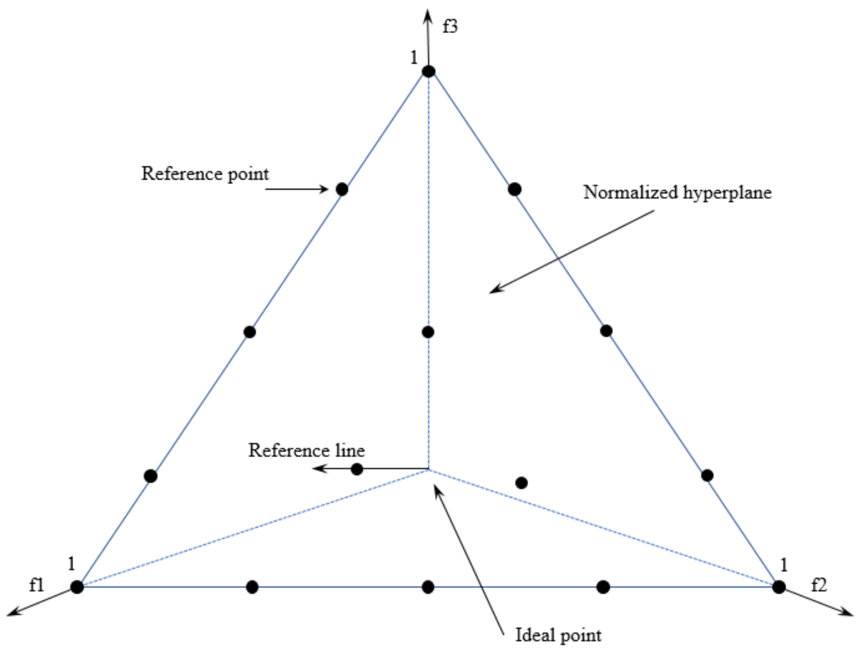
The sharing parameter of NSGA is replaced by a crowded-comparison approach since the output of the method depends on the sharing value chosen by the decision maker. Furthermore, the novel approach again should reduce complexity. Therefore, crowding distance is used as selection operator and population is initially sorted in ascending order according to each objective function value. The distance between the next smaller and the next larger value is assigned to each solution. Infinite distance values are assigned to boundary solutions so that they receive a particularly good evaluation. With all assigned distance metrics, comparison can be done between two solutions according to their degree of proximity, by which a smaller value means that the solution is more crowded with other solutions. With the nondomination rank and the crowding distance, two selection parameters are used. Primarily, the solution with the lower domination rank is preferred, so the focus is on the fronts. If two solutions of the same front are examined, the solution with the higher crowding distance is favored (Deb, et al., 2002).

NSGA-II starts with the initialization of a parent population randomly. To guarantee elitism, this parent population is combined with its offspring population and the best individuals of this outcome are taken. Therefore, this combined population is first sorted according to nondomination levels, also called fronts. Starting with the best front, each level is selected to generate a new population. A rank based on its nondomination level is assigned and solutions of the best nondominated set must be preferred and therefore an infinite distance value is assigned. Generally, the count of solutions in all sets is higher than the size of population and that is why some individuals are rejected from the combined population. In most problems, individuals of the last front are rejected. That is the reason why crowding distance must be calculated and the resulting sorting procedure of the last front according to the crowded-comparison operator is made and with these best solutions, population slots are filled. For reproduction, individuals are chosen through binary tournament selection with a selection criterion based on the crowded-comparison operator and together with crossover and mutation operators, a new population is created until a stopping criterion is fulfilled (Deb, et al., 2002).

2.3.7. NSGA-III

The basis of the Nondominated Sorting Genetic Algorithm-III (NSGA-III) or many-objective NSGA-II is the framework of the above described NSGA-II with changes in the selection operator, i.e. the crowding distance operator is replaced. The main difference to NSGA-II is the use of reference points that are either predefined points or generated in a way the decision maker prefers. In NSGA-III, the same process of finding nondomination levels is used. The systematic approach is used for determining the reference points and locates these points on a normalized hyperplane. The number of reference points depends on the number of objectives. The normalized reference plane is inclined in equal measure to all objective axes and has one point of intersection on each axis, as can be seen in Figure 2. With this approach, reference points are all placed on the normalized hyperplane. Then, the best values for all objectives and the subsequent ideal point is constructed by normalizing objective functions. A reference line, connecting every reference point on the reference plane with the origin, is constructed and the Euclidian distance of each individual to each reference line is computed (Deb & Jain, 2014).

Figure 2: Normalized reference plane



own illustration based on (Deb & Jain, 2014)

Every individual then is associated with its closest reference point in the objective space. The number of associated points is counted – so called niche count – because every reference point is likely to have a different number of individuals associated with it. The reference points with the minimum niche count are taken; if more than one reference point with the same niche count exists, it can be chosen randomly. If niche count is equal to zero, two situations are possible. If there are members in the last included front associated with this reference point, the member with the minimum vertical distance is assigned to the next generation and niche count is increased by one. In the second situation, no individual in the last included front is associated, so this reference point is excluded and another one with a niche count of zero is taken. If niche count is at least equal to one, the individual with the minimum vertical distance in the last front is added to the next generation and again, niche count is increased by one until the population size reaches its maximum. After generating the next generation, an offspring population is created through crossover and mutation operations by picking parents randomly (Deb & Jain, 2014).

3. Humanitarian logistics

The area of humanitarian logistics can be classified into the two mainstreams of disaster relief operations and supporting developing nations permanently while both share the objective to save as many lives as possible (Kovács & Spens, 2007). Golden et al. (2014, p.3) define a disaster as *"an extraordinary event that can occur with or without limited forewarning and has devastating effects on the population"*. Underlying cause may be natural or manmade, whereby examples of the former are earthquakes, volcanic eruption and tsunamis or hurricanes and for the latter, terror attacks or industry disasters. Another problem that must not be underestimated is the existing possibility that one disaster may be the trigger for another one (Golden, et al., 2014). Such an accident happened on 11th March 2011 in Fukushima. An earthquake of magnitude 9.0 created a tsunami, disabling the cooling of three reactors causing a disastrous nuclear accident. Approximately 19,000 people died as a consequence of the earthquake and tsunami, and over 100,000 inhabitants had to be evacuated (World Nuclear Association, 2016). More than four years after the disaster, people were allowed to return permanently to a village near the disaster area (ORF, 2015). Usually, local emergency units are not able to handle consequences on their own, so national and international aid agencies are of high importance when supporting the affected region regarding minimization of damage and moderation of suffering (Golden, et al., 2014). From 2000 to 2016, 7,029 natural disasters occurred worldwide, affected more than 3.5 billion people and caused total damage in the amount of US$ 1.92 trillion. Nearly 36 million people lost their homes and over 1.2 million people lost their lives (EM-DAT, 2017). According to Thomas & Kopczak (2005), disasters are going to increase fivefold in the next fifty years and therefore, research concerning this topic is going to be more important than ever. As logistic operations comprise 80 percent of disaster relief operations, they are important (Kovács & Spens, 2007).

Regarding the flow of transportation and goods, Stephenson (1993) worked out a basic concept for international relief operations, starting with a point of entry, most commonly a port or an airport in the affected region. Afterwards, commodities are delivered to a primary warehouse nearby and afterwards transported to a forward warehouse for holding. Before victims receive goods directly or indirectly, the goods are transferred to a terminal storage point. This supply chain can be parted into long-haul and forward supply, where long-haul trucks or trains accomplish the first part of this transportation process over distances of at least 1,000 kilometers and small vehicles execute last-mile distribution of commodities and transport them to beneficiaries. Typically, vehicles for last-mile distribution have to overcome more difficult routes, because infrastructure is destabilized and the probability of destroyed roads and damaged bridges as consequence of a disaster is extremely high (Stephenson, 1993).

Logistic operations have to face difficulties that are not common in daily business, such as shortage of vehicles and fuel or denial of deliverer to operate because of the risk of looting. Furthermore, decisions have to be made as quickly as possible, because rescue teams from all over the world are able to arrive within the first 24 hours after a disaster has happened. They do not have time to wait for the results of optimization algorithms but have to react immediately. Efficiency regarding computation time is of extreme importance and can save lives. Nevertheless, reduction of suffering is no quantitative measure for an optimization problem and thus cannot be used as objective. Therefore, Golden et al. (2014) define the following three particular objectives: time, number of affected people and paying fair attention to everyone. Clearly, time is one of the most important factors when it comes to saving as many lives as possible. Likewise, the number of affected people is high after a disaster strikes, and as a consequence, supply may be inadequate. As already mentioned, transportation might be difficult due to road destruction, and Vehicle Routing Problems (VRP) can be used for maximization of supply for affected people. Although the cost factor is neither a humanitarian objective nor the most important one, it must not be neglected. Right after a disaster, attention and therefore donations are high, but in later phases of disaster management, costs have to be considered more particularly (Golden, et al., 2014).

3.1. Four-stage disaster management cycle

Generally, in literature, disaster management is parted into either three or four phases. When talking about three phases, authors refer to preparation, immediate response and reconstruction, such as do Kovács & Spens (2007). Others structure in phases of mitigation, preparedness, response and recovery, as for instance Golden, et al. (2014). In approaches with three phases, authors most commonly subsume the mitigation and preparedness phases, because these two phases happen before a disaster strikes. In this work, the approach with four phases is selected, since this classification is shared more often in literature, although not many research articles deal with MOP in the mitigation phase. The cycle of the phases starts when recovery operations of a disaster have finished, since in the same moment, mitigation for the next disaster starts.

3.1.1. Mitigation

As already mentioned, mitigation is the first phase of disaster management. In this phase, people try to minimize the effects of a disaster and reduce possible damaging effects of inevitable catastrophes by proactive measures. The purpose is to be as ready as possible, if a disaster strikes, in order to alleviate human suffering. Examples of activities in this special phase are reinforcement of edifices in case of an earthquake or a flood as well as vulnerability analysis (Golden, et al., 2014).

3.1.2. Preparedness

As its name implies, the preparedness phase is about preparing for a disaster before it occurs and planning how to respond. Measures in this phase can be referred to the logistical readiness to deal with disasters. First-aid kits, food, medicine, tents or clothes should be stocked in case of a catastrophe. Response time after a disaster strikes is determined by preparation and therefore, good preparation can save lives. Problematic is the fact that neither location nor extent of the disaster is known in advance and for that reason, preparing for a disaster is quite difficult (Golden, et al., 2014). According to Kovács and Spens (2007), Tokyo, San Francisco and Reykjavik are more likely to be hit by major earthquakes and therefore have to prepare for such a situation, for example with an evacuation plan and its training or early warning systems. A problem in this phase is the fact that financial donations are meager, because donors are more likely to spend money directly on victims after a disaster strikes and not before. Moreover, research in this phase often assumes a specific disaster situation with existing input data, and, therefore, focuses on evacuation and preparedness plans for a predicted disaster, which will not be the case in reality. However, relief goods can be stored in advance since water, medicine, shelter and food are always needed in an emergency (Kovács & Spens, 2007).

3.1.3. Response

In case of an imminent disaster, preparedness plans have to be put into practice and humanitarian action starts. In the response phase, it is all about efficiently coordinating resources right after an emergency event. The main objective is minimizing suffering of affected people and reducing economic losses. Evacuation of people, opening shelters and providing medical aid are examples of short-term actions that have to be taken. Costs play a role, but not an important one in this phase; instead, time is determinant (Golden, et al., 2014). Problems this phase has to deal with are destabilized infrastructure, collapsed buildings and therefore lots of debris and unknown parameters, such as demand. Therefore, many assumptions have to be made since relief organizations are not yet on-site and have a lack of information. Due to damaged streets, a last-mile problem occurs, partly because some of the needed transported medication requires temperature control (Kovács & Spens, 2007).

3.1.4. Recovery

There is no distinct point at which response changes into the recovery phase, but after the situation is under control and injured people are under medical treatment, affected people start with restoration of self-sufficiency, infrastructure and in general, their lives. The purpose of this phase is to restore the system as well as possible, and it ends when this condition is achieved. Debris has to be removed and long-term supply of water, medicine and food has to be guaranteed. Here, the cost factor is a main problem since funding is often focused on the immediate disaster relief (Kovács & Spens (2007) and Golden, et al. (2014)).

3.2. Objectives in disaster management

De la Torre, et al. (2012) present the following different objectives in their research paper *Disaster relief routing: Integrated research and practice*: One of the most common objectives is the economic criterion of minimizing costs, which may be travel costs, inventory costs or a combination of both. In humanitarian logistics, the cost factor should not be neglected, but it is not the most important one. Gutjahr & Nolz (2016) state that the category of logistic costs is often used in literature, and furthermore, structure these costs into fixed procurement costs, supply-side traveling costs, facility-related costs and human resource costs. They point out that costs are not the most important factor, but they are considered – at least as a budget constraint – and influence the solution.

Also, minimizing latest arrival time is a relevant objective, since it assures that the point in time of the latest arrival of relief aid is as short as possible. Similarly, the objective of minimizing total response time tries to deliver relief goods to all victims as quickly as possible and hence, minimizes total arrival time. Such objectives should add the factor of equality in distributing goods, often resulting in higher transportation costs (de la Torre, et al., 2012). This is not to be confused with minimizing total driving time, and therefore, Gutjahr & Nolz (2016) recommend considering response time separately. One can weigh response time by allocating priorities to areas depending on the degree of damage - that is the reason response time and driving time are not the same (Gutjahr & Nolz, 2016).

A decision to take is if the optimization model should fulfill all demand or not. A compromise that can be made is to minimize total unsatisfied demand as well as latest arrival time. Then, quantity and speed are considered, but not all demand is satisfied. An alternative is the minimization of total unsatisfied demand with the additional objective that all people concerned receive a minimum amount of goods. This guarantees that everyone gets relief goods and that a minimum standard is satisfied. If a disaster strikes, the objective of minimizing unsatisfied demand ought to have a higher importance. This goal may be fulfilled when unsatisfied demand over time is minimized or maximum unsatisfied demand in total is minimized (de la Torre, et al., 2012). Gutjahr & Nolz (2016) refer to this objective as "coverage" and found a different definition referring to the distance of victims to the next shelter. If this distance does not exceed a certain threshold, people are "covered". Here, the factor of fairness comes into play and differentiation becomes blurred. Nevertheless, the objective of equity meaning distributional fairness is mentioned but hard to model. Mostly, people are grouped geographically, independent of social status or characteristics (Gutjahr & Nolz, 2016). Considering the objectives of speed and equality, it can be said that the factor of speed is probably the more important one immediately after a disaster. When it comes to long-term recovery, equality in delivering relief goods becomes more relevant (de la Torre, et al., 2012).

According to Gutjahr & Nolz (2016), the objective of travel distance has to be differentiated in supply-side as well as demand-side travel distance. In their literature review, the first is already taken into consideration in the cost and response time objectives. Demand-side travel distance is about distances victims have to overcome to get to the next shelter. These distances should be as small as possible (Gutjahr & Nolz, 2016).

An objective typical for optimization in disaster situations is maximization of travel reliability. This objective considers reliability of vehicles and assures that the probability for trucks to arrive at their target is as high as possible. Robbery while transporting relief goods is a real concern that has to be given attention; some models route vehicles in a convoy to avoid this (de la Torre, et al., 2012). Gutjahr & Nolz (2016) subsume natural and socioeconomic environmental factors under the category of reliability including the consideration of aftershocks of an earthquake or rising flood levels. Here, reliability is the probability of being successful. Plunder and assault are classified in the objective of security (Gutjahr & Nolz, 2016).

The last objective, Gutjahr & Nolz (2016) refer to is distress and with it psychological or social costs which are, of course, hard to measure. Deprivation, pain, anxiety and negative emotions of victims come with this objective. An approach is to measure the waiting time, i.e. the time a relief good fully satisfied the victims in relation to the actual time. This can be valued by the willingness to pay for receiving this good again. Also, waiting time until debris is removed can be seen as an objective of the category of distress (Gutjahr & Nolz, 2016).

A problem disaster management has to face is a high degree of uncertainty, requiring stochastic models instead of deterministic ones. After a catastrophe has happened, many factors such as supply, demand or travel time may not be exactly known. This means that quantity of goods that can be distributed may be uncertain due to delays and also losses. If relief goods are stocked in a warehouse and this warehouse is destroyed due to the disaster, goods are not available anymore and cannot be transported to victims. Demand, and with it the amount of goods needed, can be uncertain. It is quite possible that humans travel to places where they assume will be more relief goods and help from organizations. A worse situation would be the outbreak of a disease due to the close contact of people in shelter. Also, travel time may be stochastic. A consequence of a disaster may be destroyed bridges or non-passable streets and, therefore, the shortest path is not available any more. That is why two-stage models are often used, in which the first stage decisions are made without knowing factors for certain. These decisions are often made before a disaster strikes and include factors such as where to locate and open warehouses with relief goods, creating routes for vehicles or prepositioning of relief aid between depots. In the second stage, after the uncertain factor is known, delivery quantities can be transported to victims, and vehicles can be routed (de la Torre, et al., 2012).

3.3. Too important to fail

"*Humanitarian Aid – too important to fail*" was the title of a panel discussion in the Austrian Parliament on June 29th, 2016, at which the most important tasks and possibilities for effective humanitarian aid and the need for action due to refugee movement and disasters were discussed. Participants of the event, initiated by the former Second President of the National Council of Austria Karlheinz Kopf, were UN (United Nations) emergency relief coordinator Kyung-wha Kang, PhD, MA, BA, Claus Haugaard Sørensen, MA, BA, former Director General of European Civil Protection and Humanitarian Aid Operations (ECHO) of EU Commission, Petra Bayr, MA, Member of the Austrian Parliament, Mag. Peter Launsky-Tieffenthal, Director General of the development department in the Foreign Ministry, the Secretary General of the Austrian Red Cross Dr. Werner Kerschbaum and the Secretary General for International Cooperation of Caritas. Christoph Schweifer. The discussion was moderated by Mag.a Annelies Vilim, Director of the umbrella organization Global Responsibility – Platform for Development and Humanitarian Aid.

Karlheinz Kopf opened the discussion with the following words *"The humanitarian emergency has reached an unprecedented scale"*. Approximately 125 million people are in need of humanitarian aid and 60 million people escape violence all over the world. A main task is the provision of adequate funds, but it is also a question of increased political effort to find solutions. Kopf highlighted that Austria has already increased and is going to accelerate efforts.

Kyung-wha Kang pointed out that efficient cooperation is important for preventing conflicts and helping victims. Another factor she emphasized was disposition of financial assistance and the fact that local authorities should be better able to respond to crises. Sørensen said that one billion people are affected by disasters, starvation and conflicts, and the point is to start by reducing the risk that brings humans in these situations. For long-term planning, a long-term financial guarantee for humanitarian aid would be of great importance. Until now, funds have been guaranteed for not longer than a year, and Sørensen underlined that it would be crucial to have an assurance for at least the following year, too. Launsky-Tieffenthal argued in support of strict observance of international humanitarian law and the protection of civilian populations. Austria has taken measures ranging from peace training to early warning systems for extreme weather events. In 2017, Austria will contribute € 160 million to the World Bank's International Development Association (IDA) and overall, this support for humanitarian aid is as high as it has been for a long time. Kerschbaum additionally raised the problem that in conflicts, international humanitarian law is not always respected and that for instance in Syria, 60 per cent of health care facilities have been destroyed. If foundations of international law such as civil protection and the Geneva Convention were respected, suffering and the need for humanitarian aid could be reduced significantly. Schweifer described the dramatic situation in Ethiopia due to persistent drought. Caritas contributes to the fact that more people are better prepared for crises and are able to overcome poverty in the long term. Therefore, it is also important to recognize the importance of local partners and strengthen local NGOs (Non-Governmental Organization) instead of imposing international aid on the country ((Podium discussion at the Austrian Parliament, 29.06.2016) and (Parlamentskorrespondenz, 2016)).

4. Multi-objective optimization in disaster management

In humanitarian logistics, the right amount of relief goods has to be delivered to the right place at the right time. Efficient as well as effective procedures for solving these problems have to be defined, due to the fact that real world problems and especially the extreme case of a disaster are large-scale problems and traditional approaches can hardly be applied (Barzinpour & Esmaeili, 2014). In urban areas, the most important effort considering MOP would include the

> *"establishment of a rescue command center, collection of information (...), identification of appropriate sites for shelters, determination of the best evacuation routes, transportation for evacuation and delivery of relief materials, installation of medical and fire-prevention and emergency construction facilities"* (Tzeng, et al., 2007, p. 674).

Theory insists that local suppliers should be preferred instead of international suppliers, because of the following support of local economy. Also, storage of undesirable goods might occur during the response period, if too many goods are delivered.

In a few studies, Tehran – the capital city of Iran – is used in case studies since recent investigations show that Tehran is in an earthquake zone, and approximately eight million people live in high-risk areas (Bozorgi-Amiri & Asvadi, 2015).

In the following, articles are assigned to their covered objectives. Although cost is not the most important objective to optimize in disaster management, it is nevertheless a factor that is considered in research papers. The following two tables show the reviewed articles. Table 1 illustrates general information about the review papers. It can be seen, that most of the articles were published between 2012 and 2014 with two exceptions. Ortuno, M. et al. as well as Vitoriano, B. et al. were published in 2011. Nevertheless, they are reviewed because these are preliminary studies to Liberatore, F. et al. and it is interesting and relevant to see, how optimization models are extended and learning effects are achieved. Furthermore, only articles with a SCImago Journal Rank indicator of Q1 are chosen. This indicator is a measure of journal's *"impact, influence or prestige. It expresses the average number of weighted citations received in the selected year (author's note: 2017) by the documents published in the journal in the three previous years."* (Scimago Lab, 2017). Also, a good mix of decision models was intended. Finally, geographic background of the organizations publishing the articles were considered, most of the times universities. As can be seen here, organizational background reaches from Canada to Austria and Spain, Iran, Taiwan as well as China.

Table 1: Reviewed articles - general information

Authors (year)	**Article**	**Journal**	**DM**	**Phase**	**Geographic background**	**Use of**
Barzinpour, E. & Esmaeili, V. (2014)	A multi-objective relief chain location distribution model for urban disaster management	The International Journal of Advanced Manufacturing Technology	GP	Prep	Tehran, Iran	DMO
Esmaeili, V. & Barzinpour, E. (2014)	Integrated decision making model for urban disaster management: A multi-objective genetic algorithm approach	International Journal of Industrial Engineering Computations	Scal	Prep, resp	Tehran, Iran	DMO
Rath, S. & Gutjahr, W. (2014)	A math-heuristic for the warehouse location-routing problem in disaster relief	Computers & Operations Research	PO	resp	Vienna, Austria	DMO
Tricoire, F. et al. (2012)	The bi-objective stochastic covering tour problem	Computers & Operations Research	PO	Resp	Vienna, Austria	MOU
Bozorgi-Amiri, A. et al. (2013)	A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty	OR Spectrum	CP	Prep, resp	Tehran, Iran	MOU
Chang et al. (2014)	Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling	Expert Systems with Applications	PO	Resp	Kaohsiung, Taiwan	DMO
Abounacer et al. (2014)	An exact solution approach for multi-objective location-transportation problem for disaster response	Operations Research	PO	Resp	Quebec, Canada	DMO
Wang et al. (2014)	Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake	Transportation Research Part E: Logistics and Transportation Review	PO	Resp	Wuhan, China	DMO
Hu & Sheu (2013)	Post-disaster debris reverse logistics management under psychological cost minimization	Transportation Research Part B: Methodological	Scal	Resp	Shanghai, China	DMO
Sheu & Pan (2014)	A method for designing centralized emergency supply network to respond to large-scale natural disasters	Transportation Research Part B: Methodological	Scal	Resp	Taipei, Taiwan	DMO
Ortuno, M. et al. (2011)	A lexicographical goal programming based decision support system for logisitics of Humanitarian Aid	Computers & Operations Research	GP	Resp	Madrid, Spain	DMO
Vitoriano, B. et al. (2011)	A multi-criteria optimization model for humanitarian aid distribution	Transportation Research Part E: Logistics and Transportation Review	GP	Resp	Madrid, Spain	DMO
Liberatore, F. et al. (2014)	A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics	Computers & Operations Research	Lex, CP	Rec	Madrid, Spain	DMO

Table 2 shows the same articles with respect to methods, objectives and decision models of used optimization problems. An overview of the quantity of objectives is given, as well as information on the solution method, i.e. if the problem is solved exactly or heuristically. Here, a good mixture is achieved, and the table is ordered by solution method. If the problem is solved heuristically, the used method is put in brackets. Also, the problem type is depicted and obviously, most of the articles treat location/allocation problems when it comes to optimization in disaster management. For a better comparability, decision model types as well as phases in disaster management are shown again. When choosing the articles, the focus was on the applied solution method. If the problem is solved heuristically, the same solution method shouldn't be used twice, so reviews articles cover Nondominated Sorting Genetic Algorithm NSGA-II, Non-dominated Sorting Differential Evolution (NSDE) algorithms, Greegy-Search-based Multi-Objective Genetic Algorithm (GSMOGA), e-constraint method and constraint pool heuristic with multi-objective mixed integer linear programming (MILP) and variable neighborhood search (VNS).

Table 2: Reviewed articles - methods, objectives and decision models

Authors (year)	Article	Solution method	OF	Objectives	DM	Problem type	Phase	Case study
Wang et al. (2014)	Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake	Heur (NSGA-II, NSDE)	3	F_1: min max travelling time F_2: min cost F_3: max min reliability	PO	Loc/all, transp	Resp	Earthquake: Sichuan, China
Chang et al. (2014)	Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling	Heur (GSMOGA)	3	F_1: min uncovered demand F_2: min response time F_3: min cost	PO	Transp	Resp	Earthquake: Taiwan
Esmaeili, V. & Barzinpour, E. (2014)	Integrated decision making model for urban disaster management: A multi-objective genetic algorithm approach	Heur (GA)	3	F_1: max coverage F_2: min cost F_3: max coverage	Scal	Loc/all, transp	Prep, resp	Earthquake: Tehran, Iran
Abounacer et al. (2014)	An exact solution approach for multi-objective location-transportation problem for disaster response	Exact, heur (ε-constraint method)	3	F_1: min response time F_2: min number of agents F_3: min uncovered demand	PO	Loc/all, transp	Resp	—
Rath, S. & Gutjahr, W. (2014)	A math-heuristic for the warehouse location-routing problem in disaster relief	Exact, heur (constraint pool heuristic with MILP & VNS)	3	F_1: min cost (opening) F_2: min cost (operative) F_3: max coverage	PO	Loc/all, transp	resp	Earthquake: Manabí, Ecuador
Barzinpour, E. & Esmaeili, V. (2014)	A multi-objective relief chain location distribution model for urban disaster management	Exact	3	F_1: max coverage F_2: min cost F_3: min cost	GP	Loc/all, transp	Prep	Earthquake: Tehran, Iran
Tricoire, F. et al. (2012)	The bi-objective stochastic covering tour problem	Exact	2	F_1: min cost F_2: min uncovered demand	PO	Loc/all, transp	Resp	Example of Senegal
Bozorgi-Amiri, A. et al. (2013)	A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty	Exact	2	F_1: min cost F_2: min sum of max shortage	CP	Loc/all, transp	Prep, resp	Earthquake: Iran
Hu & Sheu (2013)	Post-disaster debris reverse logistics management under psychological cost minimization	Exact	3	F_1: min cost F_2: min risk penalty F_3: min distress	Scal	Transp, invent	Resp	Earthquake: Wenchuan, China
Sheu & Pan (2014)	A method for designing centralized emergency supply network to respond to large-scale natural disasters	Exact	3	F_1: min travelling distance F_2: min cost F_3: min distress	Scal	Loc/all, transp	Resp	Typhoon: Linbian & Jiadong: Taiwan

Authors (year)	Article	Solution method	OF	Objectives	DM	Problem type	Phase	Case study
Ortuno, M. et al. (2011)	A lexicographical goal programming based decision support system for logisitics of Humanitarian Aid	Exact	2	F_1: max coverage F_2: min deviation Attributes: cost, response time, equity, priority (coverage), reliability, security	GP	Transp	Resp	Food crisis: Niger
Vitoriano, B. et al. (2011)	A multi-criteria optimization model for humanitarian aid distribution	Exact	1	F_1: min deviation Attributes: cost, response time, equity, coverage, reliability, security	GP	Loc/all, transp	Resp	Earthquake: Haiti
Liberatore, F. et al. (2014)	A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics	Exact	3	F_1: max coverage F_2: min of infinity norm distances F_3: min of norm distances Attributes: cost, response time, reliability, security	Lex, CP	Loc/all, transp	Rec	Earthquake: Haiti

Heur = heuristic; NSGA = Nondominated Sorting Genetic Algorithm; NSDE = Non-dominated Sorting Differential Evolution; GSMOGA = Greegy-Search-based Multi-Objective Genetic Algorithm; GA = Genetic Algorithm; MILP = multi-objective mixed integer linear programming; VNS = variable neighborhood search; PO = Pareto Optimization; Scal = Scalarization; GP = Goal Programming; Lex = Lexicographic optimization; CP = Compromise Programming; Loc/all = Location/allocation; Transp = Transportation; invent = inventory; Phases: Prep = Preparedness; Resp = Response; Rec = Recovery

4.1. Coverage and cost

In this first section, the following articles are reviewed with either two of three objectives considering cost or coverage:

- Barzinpour, E. & Esmaeili, V. (2014): *A multi-objective relief chain location distribution model for urban disaster management*
- Esmaeili, V. & Barzinpour, E. (2014): *Integrated decision making model for urban disaster management: A multi-objective genetic algorithm approach*
- Rath, S. & Gutjahr, W. (2014): *A math-heuristic for the warehouse location-routing problem in disaster relief*

An article dealing with simultaneous optimization of cost and coverage was written by Barzinpour & Esmaeili (2014) and proposes a new multi-objective mixed integer linear programming (MILP) model. The proposed model is developed for the preparation planning phase, i.e. before a disaster happens. Furthermore, it is inspired by a real case study of an urban district in Iran and uses real data of a local district in Tehran, consisting of ten subregional areas with more than 350,000 inhabitants. The authors present a two-echelon relief chain location allocation distribution model with the goal to maximize coverage of population and at the same time minimize logistic costs. The relief chain is composed of local bases as centers for distribution and regional and subregional areas forming demand pixels. These demand pixels can be parted into four kinds, depending on the vulnerability. Red areas depict zones that are the most critical, yellow zones are the second worst ones, followed by green and blue as zones with the best conditions. In blue zones, 12 to 75 buildings might be destroyed, whereas in red zones up to 202 buildings might be affected. Data envelopment analysis (DEA) is used proactively to estimate vulnerabilities and create a ranking system. Tehran is most likely to be affected by an earthquake, and that is the reason damages from a hypothetical earthquake with a magnitude of 7.2 on the Richter scale which occurs at midnight in the north is estimated. Information of this estimation (composed of factors such as total population, distribution of building types or ground conditions) is used as input for the mathematical model. The main objectives in this simple maximal covering model are the following (Barzinpour & Esmaeili, 2014):

- F_1: maximization of cumulative coverage of population in pixels of the region
- F_2: minimization of total facility setup costs
- F_3: minimization of total transportation costs, equipment holding costs and shortage penalty costs for equipment and supplies

Although F_2 and F_3 both minimize costs, they have to be considered separately, because fulfilling F_2 automatically has an increase of transportation costs as consequence. Since one constraint is nonlinear, a fact that complicated the computational effort, linearization technique is applied to transform it into a linear constraint (Barzinpour & Esmaeili, 2014).

The mathematical model is solved with a lexicographic goal programming approach. Here, experts of local authorities determine the following priority of objectives with the aim of having the least deviation from goals set for budget as well as coverage: the objective considering maximization of coverage has first priority, because the most important goal in disaster management is providing disaster victims with relief goods. Since location decisions are strategic and of high investment, F_2 is the objective with the second highest priority. Decisions of objective F_3, considering other logistic costs, are tactical with lower significance and therefore are the objective with least priority. These additional equations are added to the model (Barzinpour & Esmaeili, 2014).

Since it is a large-scale problem, solving the model traditionally with for instance "branch and bound" would be nearly impossible in a rational amount of time. For that reason, the problem is divided into its ten subregional areas, since each local base delivers only in its own local domain. These smaller optimization problems can be solved with common optimization software. Additionally, virtual zoning has been made for supplementary cells, by which each cell implies more local subregions to encourage cooperation of neighbor blocks. The problem is solved with and without virtual zones, and comparing computational results shows that with virtual zones, efficiency and effectiveness is increased simultaneously in all three objectives. In other words, cooperation between subregions can highly improve financial as well as humanitarian goals (Barzinpour & Esmaeili, 2014).

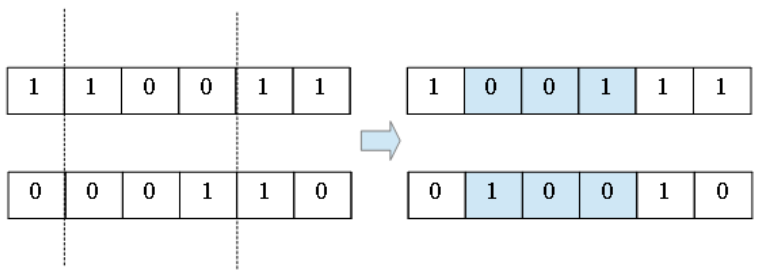
In the article "Integrated decision making model for urban disaster management: A multi-objective genetic algorithm approach", the same authors develop a multi-objective mathematical model for location-distribution problem and use a GA to solve the model.

Local emergency management bases should be located and affected people should then be allocated to these bases. The authors include the findings of their previous research and take the effects of neighbors into consideration. This article addresses the main issue of number and location of emergency bases, and furthermore, coverage of urban cells inside the district as well as in an exterior area, and finally the inventory level in each emergency base and distribution of stored relief goods. Demand in exterior areas can be interpreted as unknown demand from a neighbor local block that cannot be ignored and is estimated based on probabilistic parameters. As in the previous article, an earthquake in the urban districts of Tehran is considered with 10 zones and the same classification into four colored zones – red, yellow, green, blue – depending on the number of predicted devastated buildings. The objectives of the mathematical model are the following (Esmaeili & Barzinpour, 2014):

- F_1: maximization of covered demand inside the local region
- F_2: minimization of total facility set-up costs, tactical and operational costs (such as transportation- shortage- or inventory holding costs)
- F_3: maximization of percentage of covered demand outside the local region

The mathematical problem is solved with a GA. Referring to the characterization of GAs in chapter 2.3.4 – Genetic Algorithm, specific adaptations made for solving this mathematical model are delineated now. Regarding representation of chromosomes, Esmaeili & Barzinpour (2014) determined that each chromosome represents a solution consisting of all decision variables and for each a relative matrix forms a starting solution. A barrier function forms the fitness function composed of normalized values of objective functions and penalties if a constraint is violated. Initialization of population is, as usual, generated randomly and following this, the fitness function is defined for every chromosome. After parents are selected via the fitness function, crossover and mutation operators are used with a given probability, whereas mutation is less probable to happen and should generate just one offspring from one parental chromosome. Therefore, a part of the process of simulated annealing with a cooling mechanism is used to generate an offspring with a higher chance for a better fitness function and, as a result, with a higher chance to be selected as new parents (Esmaeili & Barzinpour, 2014). For the crossover operator, the authors use traditional crossover technique, depicted in Figure 3:

Figure 3: Crossover operator for GA



own illustration

The crossover operator slightly changes information of the selected parents. Two cut points are chosen randomly on selected parent chromosomes, indicated as dashed lines in Figure 3 on the left side. The strings outside the lines are copied one-to-one to the offspring on the right side in the illustration. The parts between the lines are changed amongst parents with the result that two complete new strings emerge with part of both parents.

The last operator of the GA selects chromosomes that should make it into the next generation. As mentioned earlier, only the fittest chromosomes are selected to be parents and create offspring and two possible classifications can be implemented, i.e. selecting only chromosomes of the offspring population or alternatively, selecting chromosomes of both, parental as well as offspring population. Considering this, a percentage of the best chromosomes of parents and offspring and additionally, a percentage of randomly chosen chromosomes are selected. The GA stops when a certain stopping criterion is achieved; in this case the GA stops if a certain number of generations is achieved (Esmaeili & Barzinpour, 2014).

The original MIP is also examined with an LP-relaxation technique where the solution represents a lower bound and solved with an optimization toll in order to test solution quality of the proposed GA. Results show that – with the applied weighting values for the fitness function and a suitable number of generations for running the GA – solutions for the GA are better than tested solution alternatives using techniques applying lower bounds. (Esmaeili & Barzinpour, 2014).

A third article covering cost and coverage factors by Rath & Gutjahr (2014) presents an optimization model which can be – contrary to the article by Barzinpour & Esmaeili

(2014) – applied after a disaster has happened. It focuses on medium-term relief, usually lasting from a few weeks up to two years after a disaster has occurred. It deals with the establishment of intermediate warehouses and maximization of demand with three objectives and applies the ε-constraint method to determine all Pareto-optimal solutions. It is composed of three objectives regarding strategic costs, operative costs and uncovered demand. After a disaster, infrastructure is very likely to be damaged and therefore, a new system of transportation has to be assured. Intermediate warehouses are needed in order to transport relief goods from the suppliers, for example, international airports, to the people in need of food, clothes, tents, medicine or other relief goods. The problem is composed of strategic and operational parts, in which the former deals with the location of the warehouses, a decision that has to be well-considered, due to the fact that it cannot be changed very easily once the warehouses are built. The assignment of disaster victims to warehouses and the routing from warehouses to victims form the operational part of the MOP. The warehouse location-routing problem (WLRP) generates the starting base of the problem formulation. With the objective to minimize costs, the number, size and location of warehouses has to be determined. Furthermore, the assignment of victims to warehouses and routes has to be decided. Overall costs are composed of warehousing cost, i.e. fixed cost and throughput cost depending on the number of delivered relief goods, as well as transportation cost. One included specific constraint is that total demand may exceed total supply, meaning that not all relief goods can be delivered. Since this difference should be as small as possible, the objective to maximize covered demand is considered. The authors assume an unlimited number of vehicles and drivers. Vehicles have a capacity restriction, but drivers can come back to the warehouse and reload as long as maximum driving time is not violated. In the model, only transportation costs from suppliers to warehouses are minimized particularly. The objective concerning maximizing demand includes optimal routing from warehouses to disaster victims. To summarize, the authors propose a three-objective optimization model with the following different functions (Rath & Gutjahr, 2014):

- F_1: minimization of fixed costs for warehouses and vehicles
- F_2: minimization of budget for operative cost
- F_3: maximization of covered demand

F_1 is a medium-term economic cost function, F_2 a short-term economic cost function and F_3 a non-monetary benefit function. F_3 conflicts with F_1 as well as with F_2. The costs of F_2 include transportation cost from suppliers to warehouses plus warehousing cost. A decrease in this operative cost will automatically lead to a decrease in covered demand (Rath & Gutjahr, 2014).

For solving the MOP, the authors use an exact method as well as a math-heuristic technique they call *constraint pool heuristic*. This heuristic uses a constraint pool in order to dynamically generate constraints for a MILP model. These constraints are generated when needed by a variable neighborhood search (VNS) algorithm. In both methods, the exact and the heuristic, an adaptive epsilon-constraint algorithm (AECA) is utilized. As already described, one objective function is chosen, and all other objective functions are restricted. Rath and Gutjahr (2011) chose F_3 as objective function for the single-objective problem and set upper bound on F_1 as well as on F_2. If this problem is solved exactly, the exact Pareto-frontier is found; otherwise an approximation is made. Results show that the constraint pool heuristic leads to good approximations and is faster than the directly solved MILP, resulting from the implementation of AECA (Rath & Gutjahr, 2014).

4.2. Coverage and cost under uncertainty

So far, previous articles have dealt with the objectives of cost and coverage under certain circumstances. The following articles handle the objectives of cost and coverage under uncertainty with, of course, more computational effort, but remarkable results.

- Tricoire, F. et al. (2012): *The bi-objective stochastic covering tour problem*
- Bozorgi-Amiri, A. et al. (2013): *A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty*

The paper by Tricoire et al (2012) presents a bi-objective two-stage stochastic program with recourse and takes into account the following objectives:

- F_1: minimization of total costs
- F_2: minimization of expected uncovered demand

Costs in this model are composed of opening costs for the distribution centers (DCs) as well as routing costs for the vehicles transporting relief goods. Uncovered demand is made up of the demand of the victims that cannot go to DCs because the distance is too long, the demand that cannot be satisfied due to capacity limits in the DCs and the demand that cannot be satisfied due to capacity limits of the vehicles (Tricoire, et al., 2012).

The basic features of the bi-objective Maximal Covering Tour Problem (MCTP) with the objectives to minimize total tour length and maximize total demand are taken and extended by particular features. The assumption of the MCPT that a node is either visited or not is adjusted accordingly, i.e. a certain percentage of disaster victims travels to DCs depending on the distance. In disaster aftermath, it is not always possible to deliver relief goods directly to victims. However, they should be transported to DCs that are nearby, such that most of the victims are able to get there within a walking distance. In their test instance, the authors assume the following: 100 percent of the population will walk to the closest DC if it is six kilometers away, and 50 percent within the reach of six to fifteen kilometers will take the walk. Another added feature is that DCs have capacity restrictions and have opening costs. Moreover, a high degree of uncertainty regarding actual demands is considered and modeled by random variables, a fact that leads to a two-stage stochastic optimization problem. At last, more than just one vehicle can be used for transporting relief goods. This problem is solved by combining a scenario-based approach with the ε-constraint method based on branch-and-cut (Tricoire, et al., 2012).

The minimization of objectives F_1 and F_2 generate the first-stage problem with the estimated uncovered demand. The actual uncovered demand is generated by solving the second-stage problem, so F_2 is the recourse function, representing the expected cost of the decision that will be made after the so far unknown values become known. In the second stage, the objective function represents minimization of uncovered demand, composed of the difference between total demand and total supply. Expected uncovered demand is approximated by a sample average in which each scenario N has the same probability to happen, a step with the consequence that the problem consists of the first-stage problem and N different versions of the second-stage problem (Tricoire, et al., 2012).

Tricoire et al. (2012) solve the mathematical problem with an exact solution algorithm based on the epsilon-constraint method as well as a heuristic solution algorithm with a modified epsilon-constraint method for also being able to solve larger instances. The modification for the heuristic method is made due to observations the authors made when testing the exact algorithm with real-life instances. For small instances, the algorithm finds all Pareto-optimal solutions in a short computation time. But, for large instances, solutions considering high cost and low uncovered demand were not found in an acceptable time. The authors came to the result that a new solution needs a higher computation time than the previous solution. Therefore, modification of the heuristic starts with determining the exact Pareto front for easy instances with a high probability and as computation continues, it reduces the accuracy for getting a good approximation to the Pareto front for more difficult instances. This reduction is made by an increase of the tolerance gap between lower and upper bound used for declaring a solution as optimal or not (Tricoire, et al., 2012).

Observing the results obtained with the exact algorithm, it can be said that instances with at most twenty nodes can all be solved within a computation time limit of three days. In the two cases of 21 nodes, one instance can be solved and the other one not. All instances with more than 21 nodes cannot be solved with the exact algorithm. All tested instances were also solved with the heuristic algorithm and looking at the first example that cannot be solved with the exact algorithm, but can be solved heuristically, it can be figured out that the heuristic algorithm finds within eight hours all solutions the exact method found in three days of computing and additionally a solution in which uncovered demand is zero. It has to be pointed out that the last found solution of the exact algorithm has a very low uncovered demand, so only a few solutions of the Pareto front were missing. Nevertheless, a computation time of more than three days is far too long when it comes to saving lives by providing food and medicine in disaster relief management (Tricoire, et al., 2012).

When it comes to applying the bi-objective stochastic covering tour problem in practice, it first of all must be filled with data, most commonly extracted from geographic information systems. Parameters of demand distribution have to be determined, but must only be updated with minor changes and, therefore, these adaptations do not take a long time. Computation of the model can be done overnight with a planning horizon of one day. After this computation, the decision maker can limit the scope of solutions after looking at the optimal Pareto front. One decision might concern costs and the choice that solutions over a certain cost factor are not taken into account or that solutions in which uncovered demand exceeds a set threshold should be eliminated. The system then shows fewer solutions based on this additional constraint the decision maker set. Such decisions can be made easier if the person in responsibility has an idea about the tradeoff between costs and their effects. Furthermore, new computation can be done in a few milliseconds, so does not take much extra time, because new solutions do not have to be generated again, but rather existing solutions just have to be run through. If only few solutions remain, these can easily be represented on maps and ease final choice for decision makers. This implies that the final decisions are made by humans and not by machines (Tricoire, et al., 2012).

Bozorgi-Amiri et al. (2013) use multicriteria optimization und uncertainty and present a multi-objective robust stochastic programming model that optimizes relief operations in preparedness and the response phase of disaster management. Uncertain parameters are demands, supplies, procurement and transportation costs; moreover, uncertainty of locations at which demand may occur and the possibility that pre-positioned supply might be destroyed as a consequence of a disaster are considered. In addition, the safety of warehouses concerning risk of destruction or stealing is included. The authors assume a two-echelon relief network as, for example, Barzinpour & Esmaeili (2014), consisting of three parts, namely suppliers, relief DCs, and affected areas, i.e. people concerned. Distribution centers should be positioned in a way that relief goods can be transported to both suppliers and affected people in an efficient way. Uncertain parameters depend on the disaster scenario and its impact, and probability that a certain scenario occurs is determined by experts or disaster planners based on historical data and geographic weaknesses. Furthermore, the model does not deal with a single-commodity problem since each commodity has a different volume and different costs associated with it. A DC can be opened in three forms, i.e. small, medium or large, each allied to setup costs. DCs can be supplied either by suppliers or by other DCs and the possibility of storage exists, even though inventory is penalized. If a DC is not able to transport to the closest demand point, due to shortfall, the second closest DC services. Considering these assumptions, objective functions are the following (Bozorgi-Amiri, et al., 2013):

- F_1: minimization of expected total costs, cost variability and expected penalty for infeasible solution
- F_2: maximization of customer satisfaction

Particularly, objective F_1 minimizes three parts, whereas the first term considers expected value of overall costs, i.e. costs of the first stage of the model and expected cost value of the second stage. To specialize, costs of the first stage are composed of costs regarding preparedness phase, i.e. setup, procurement and transportation costs from suppliers to DCs. Second-stage costs are procurement, transportation from suppliers to DCs and from DCs to persons affected, inventory holding costs and lastly, shortage costs. The second part of the first objective concerns cost variability and the last deals with robustness of the model relating to penalization of infeasible solutions. Objective F_2 is in charge of minimizing the sum of maximum shortage. For solving this problem, the authors use Compromise Programming as explained in chapter *2.3.3. Goal Programming and Compromise Programming*. Each objective is considered individually. The single objective then minimizes the sum over the normalized difference and relative optimum value based on LP-metrics method (Bozorgi-Amiri, et al., 2013).

As an area for their case study, the authors also took the decision to test a scenario for an earthquake in Iran. They consider four different scenarios with five suppliers, fifteen demand points, and water, food and shelter as commodities. Demand for water and food is estimated with respect to population density multiplied by probability of vulnerability of demand points. Probability depends on type and intensity of disaster as well as urban fabrics. Since one shelter can accommodate three people, estimated demand is set to number of affected people divided by three. LP-metrics formulation with equal relative weights is used to solve the problem. As already mentioned, LP-metrics methods consider each objective function on its own. Then, a new single objective is postulated to minimize normal difference between each value of the OFs and the optimal multi-objective value. This leads to the following results (Bozorgi-Amiri, et al., 2013).

Nine DCs are opened and the total costs of the pre-disaster phase, not subject to uncertainty, add up to approximately 35 million US dollars and the expected value of the post-disaster phase reaches 55.5 million US dollars. The expected value of maximum shortage is calculated with 521,000 units. Findings show that increasing the weight for F_1 leads to an increase in F_2, meaning less satisfaction for disaster victims. Logically, with a higher degree of uncertainty, complexity of the model increases but total costs improve compared to models with lower degrees of uncertainty. The authors wanted to underline the importance of considering uncertainty and therefore compared and tested four different models with a difference in the degree of uncertainty. The first is deterministic, the second assumes only demand uncertainty, the third additional supply uncertainty and the last, demand, supply as well as cost uncertainty. They found out that on average, cost savings of 3.8 percent can be achieved with their proposed model when testing the case problem on all four model types. Furthermore, the authors found that the last model as well has the lowest costs for each objective function. Therefore, it is recommended that decision makers should choose the proposed model with consideration of uncertainty of all sources (Bozorgi-Amiri, et al., 2013). Regarding time for running the solution procedure, the authors do not give any information. It would have been interesting to indicate how long it takes after the decision maker made the choice of trade-off, since the model is targeted for preparedness as well as the response phase of disaster management.

4.3. Response time, coverage and cost

Articles paying attention to response time and coverage, besides cost, are the following:

- Chang et al. (2014): *Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling*
- Abounacer et al. (2014): *An exact solution approach for multi-objective location-transportation problem for disaster response*

As the title implies, the Greegy-Search-based Multi-Objective Genetic Algorithm (GSMOGA) developed by Chang et al. (2014) aims to minimize the above mentioned crucial objectives with the goal to distribute relief goods as efficiently as possible and create a routing schedule with minium delay and cost.

- F_1: minimization of uncovered demand
- F_2: minimization of response time
- F_3: minimzazion of costs

The emergency logistics scheduling problem consists of input data, i.e. supply and demand points, in which supply points are locations from where commodities are distributed, and demand points are locations for unloading and dispatching. In this research, each demand point includes information regarding food and water demands, time expired and location of the demand point. In emergency centers, the logistics plan is designed and in a last step, a routing schedule is developed and forms the output of the approach. The proposed solution approach collects the above-mentioned data input in a first step and produces the shortest distance matrix with Dijkstra Algorithm, a shortest path solution approach. Initialization of populations is designed by a greedy algorithm as long as relief goods remain. After evaluation, solutions are ranked and sorted for the moment with the use of NSGAII to map individual chromosomes into a routing schedule before the approach proceeds with selection and crossover operations. Regarding the selection operator, tournament selection is chosen, where two chromosomes are selected randomly in a first step and the fitter one is chosen as first parent. Repeating this operation leads to the second parent and the emerging pair performs crossover and mutation operations. Again, a greedy algorithm is applied considering capacity, velocity and costs until termination criteria are satisfied. If mapping to routing schedules ends, an evaluation is made, and the best ranked chromosomes and routing table found again with the help of NSGA-II builds the outcome. GSMOGA is used, because it combines the benefits of the fast greedy search approach with those of multi-objective genetic algorithms (Chang, et al., 2014).

The authors tested their approach on a real world case with limited and unlimited transportation conditions. Furthermore, greedy objectives and MOGA objectives were tested separately additionally to GSMOGA. The greedy algorithm reveals one routing solution and transport is made from supply points in a fixed order. GSMOGA and MOGA use identical parameters. Regarding delivery time in the tested instances with limited transportation and with unlimited transportation, GSMOGA clearly outperforms greedy search and multi-objective GA with improvements of about 61 per cent on average with limited transportation and 46 per cent with uncapacitated transportation. Multi-objective GA shows slightly better results than greedy search in both cases but is not competitive with GSMOGA. Also, testing routing distance with limited capacity, GSMOGA finds a route that is nearly half of the route obtained by greedy search and moreover a more efficient assignment of vehicles, because it is the solution with less repeated routing lines. In conclusion, it can be said that GSMOGA outperforms greedy algorithm as well as multi-objective GA and generates more feasible routes (Chang, et al., 2014).

Abounacer et al. (2014) developed an exact solution approach for multi-objective location-transportation problem for disaster response in their same-titled article. The authors' focus is on two important and related problems, i.e. location and transportation. The first is responsible for the design of a network for needed products and the latter handles distributing products to demand points. Since both, transportation and location problems, are solved at once, it is a location-transportation problem. The authors consider three different and conflicting objectives and choose F1 to be optimized for the epsilon-constraints method (Abounacer, et al., 2014):

- F_1: minimization of total transportation duration of required products
- F_2: minimization of the number of first-aiders
- F_3: minimization of uncovered demand

With fulfillment of these objectives, the exact Pareto front is generated. A reduction of transportation duration can be achieved when opening many DCs, but this measure is in accordance with a high number of aides as well as material resources. Clearly, no one wants to bring more human beings than needed into the dangerous zone at which a disaster has occurred. First, the risk is too high, second, more food and water are needed and last, more people imply more coordination effort. However, when too few DCs are opened, capacity problems can occur, leading to unsatisfied demand. Abounacer et al. (2014) introduce demand zones in their article. Every building is a potential point where aid products and therefore demand could be needed. Due to the fact that this number perhaps is extremely high, these demand points are parted into demand zones. Since decisions are taken with currently disposable information right after a disaster strikes, the problem is regarded in a statistical and deterministic environment. Estimations based on experiences and previous disasters regarding demand are made by homeland security organizations, and estimated transportation times take into consideration infrastructure condition as well as the complexity to access the affected region. With the epsilon-constraints method, the authors determine the exact Pareto front, however, with large computational time. For that reason, an approximated method with stopping criteria is introduced as well, producing a rather good Pareto front approximation with less computation time. The authors solved the mixed integer problem (MIP) with

CPLEX solver and noticed that it took a lot of time to demonstrate that the solution is optimal. Therefore, a non-null tolerance on relative gap is enforced on the algorithm. Relative gap is defined as the gap between best lower and upper bound solution and three tolerance values, i.e. ten per cent, five per cent and one per cent are examined. If the value of relative gap is below the tolerance value, the stopping criterion is fulfilled, and the algorithm comes to an end and the solution is equivalent to the best upper bound. According to the authors, the algorithm can be used to solve any optimization problem with three objectives with at least two integer objectives that are conflicting (Abounacer, et al., 2014). It is of immense importance that an alternative algorithm is proposed, because computation time is very high. In an emergency situation, there is usually not a long time for running an algorithm since rather good decisions have to be taken immediately after a disaster stroke.

4.4. Response time, reliability and cost

- Wang et al. (2014): *Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake*

Wang et al. (2014) include among cost and response time the objective of reliability in their relief distribution problem as well as determination of DCs, vehicle routing and scheduling. Because routes and bridges may be destroyed after a disaster, connections between affected areas become uncertain. Since this uncertainty has effects on aiders on the one hand and response time on the other hand, reliability as the probability to be able to drive from one affected area to another in time is an important issue. High reliability refers to the assurance that relief commodities reach their destination soon. Therefore, heterogeneous vehicles with diverse capacities and velocities are considered. The goals of this MOP are to decide how many DCs should be opened, allocation of affected areas and vehicles to DCs and establish routing plans with respect to maximum vehicle capacity. Furthermore, split deliveries are taken into account, meaning that vehicles can deliver several times the same area, if demand exceeds maximum capacity of the truck (Wang, et al., 2014).

- F_1: minimization of maximum route time
- F_2: minimization of total cost
- F_3: maximization of minimum route reliability

F_1 can also be expressed as minimizing the latest service completion time and reliability in F_3 is defined as *"the possibility for drivers to deliver relief to all the demand points (...) successfully"* (Wang, et al., 2014, p. 162).

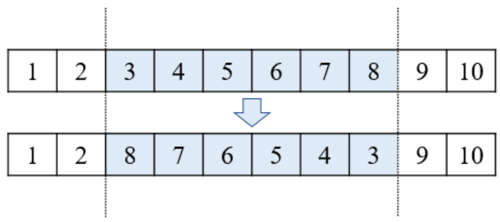
For solving this MOP, NSGA-II and Non-Dominated Sorting Differential Evolution (NSDE) algorithms are used, differentiating in mutation and crossover operators. Since results show that NSGA-II outperforms NSDE, the focus lies on NSGA-II. Here, every chromosome X_g^t is composed of three sub-strings, where g = 1, 2, …, NP is the number of chromosomes and t is the notation for the number of generations and every round bracket expresses a sub-string:

$$X_g^t = \{(x_{g11}^t, x_{g12}^t, \dots, x_{g1K}^t), (x_{g21}^t, x_{g22}^t, \dots, x_{g2K}^t), (x_{g31}^t, x_{g32}^t, \dots, x_{g3K}^t)\}$$

The first sub-string is a permutation of K vehicles and in combination with the second sub-string responsible for the decision regarding vehicle allocation. Sub-string two states the number of open DCs. The last sub-string shows a permutation of demand points and together with the first sub-string, determines the following: which vehicle serves which and how many affected areas, the sequence of service and the supplier quantity distributed to affected areas in each route, also considering maximum capacity of vehicles and updated information on demand for the next vehicle that is sent to cover demand of either the same or the next disaster zone (Wang, et al., 2014).

In NSGA-II, reverse sequence mutation, as shown in Figure 4, is applied, where two cutting points are chosen randomly and the genes insides the lines are inversed.

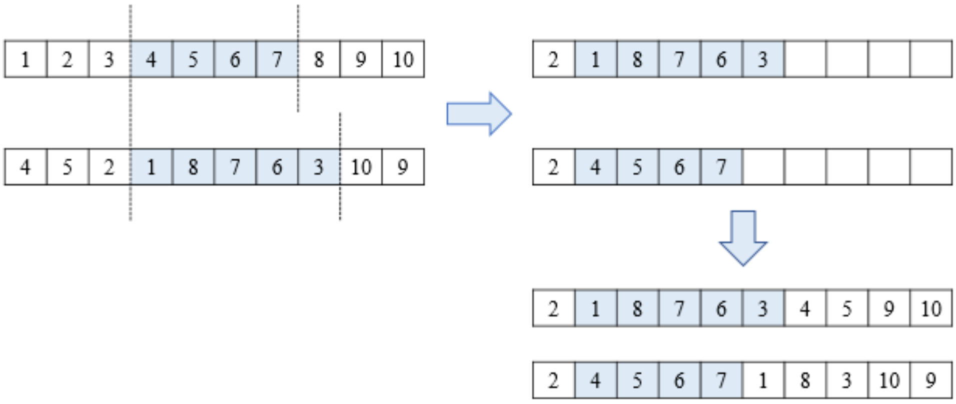
Figure 4: Reverse sequence mutation



own illustration

For producing the trial population, crossover operations are used, as depicted in Figure 5:

Figure 5: Crossover operation, NSGA-II

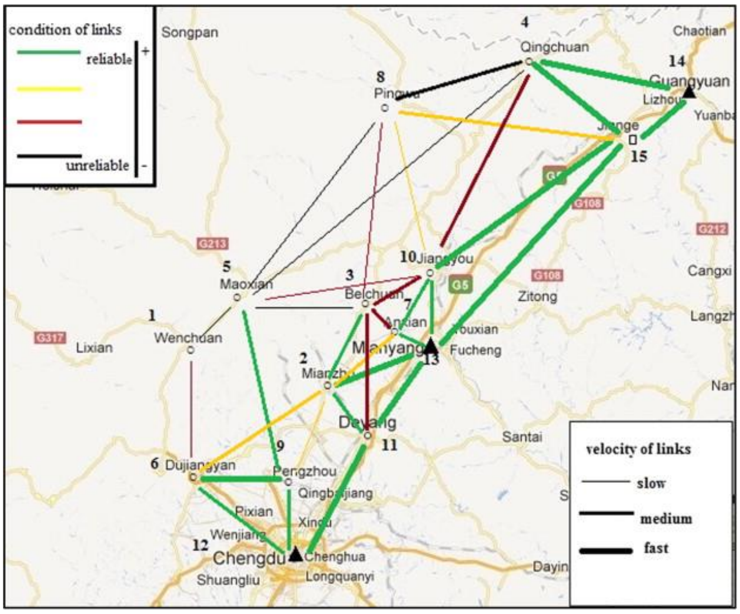


own illustration

In a first step, two cutting points are chosen randomly. Then, those genes before the first cutting point are kept that do not appear between the cutting points of the other parent chromosome, i.e. the gene 2 in both cases. Afterwards, the genes between the crossover points of the other parent chromosome, are taken, i.e. the light blue colored sequences in Figure 5. In a last step, the so far not used genes after the first cutting point of each chromosome are taken, i.e. 4, 5, 9 and 10 in the first chromosome and 1, 8, 3, 10 and 9 in the second chromosome. Fast-non-dominated-sorting operations are used for ranking solutions based on objective values. Crowding-distance-sorting operations are applied for estimating density of solutions with computing the normalized distance to the closest neighbors. The stopping criterion of NSGA-II is a maximum count of iteration times (Wang, et al., 2014).

The proposed algorithm was tested on the Great Sichuan Earthquake in China that measured 8.0 on Richter scale in the response phase of the disaster. Picture 1 shows the topology of the transportation network. Used data is taken from Google Maps. Nodes from 1 to 11 show demand points, whereas nodes from 12 to 14 show possible DCs. Node 15 depicts a transshipment node. Colors of links between demand points are colored regarding reliability, where black means unreliable and green reliable. Also, velocity of links is indicated, recognizable by the thickness of the lines, i.e. the thicker the line, the faster the vehicle. Three kinds of vehicles were taken into account with different capacity, velocity and costs per unit of length (Wang, et al., 2014).

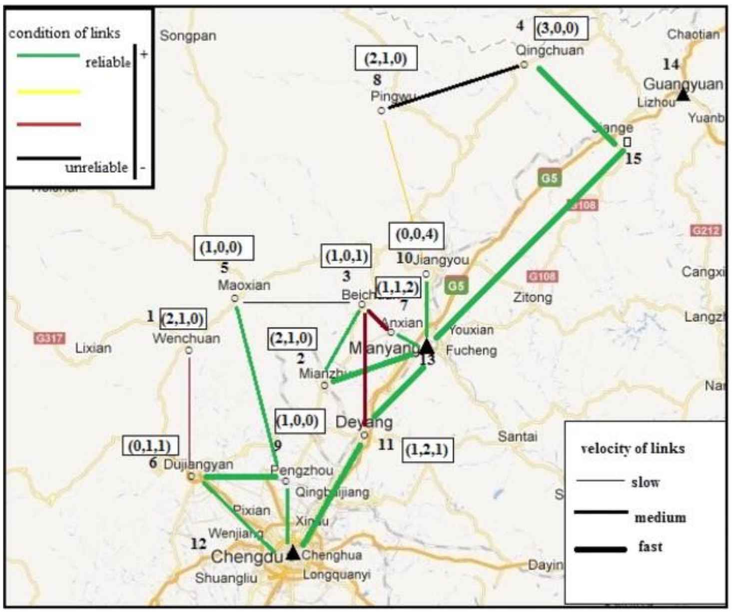
Picture 1: Transportation network in Sichuan



(Wang, et al., 2014, p. 173)

The authors assume that for realistic instances it is nearly impossible to obtain the set of all Pareto-optimal solutions exactly and therefore, in fifteen test instances, the approximate Pareto-optimal solutions should be found. The in the article presented results how the average values of these fifteen test instances. As already mentioned, NSGA-II dominated almost all solutions obtained by NSDE. With the results, decision makers can select the approximate Pareto-optimal solution depending to their preferences. The following three pictures show the obtained solutions based on the three objectives of minimization of maximum route time (Picture 2), minimization of total cost (Picture 3) and maximization of minimum route reliability (Picture 4) (Wang, et al., 2014).

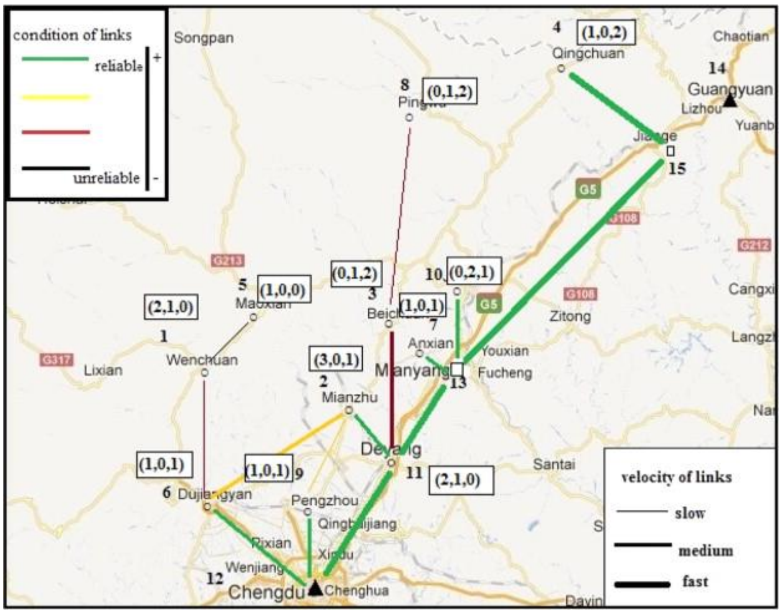
Picture 2: Solution minimization of maximum route time



(Wang, et al., 2014, p. 174)

In Picture 2, two DCs are open, i.e. node 12 and 13 and the longest computed route travelling time is 7.6 hours. Only the two fastest vehicles are used for those nodes, that are far away from DCs, reducing the maximum travelling time. Nodes that are close to DCs are served with vehicles with a smaller maximum capacity. Also, the unreliable route from node 4 to 8 is used in order to minimize maximum route time. In Picture 3 and the solution regarding minimization of total cost, it can be seen that more routes with a high travel speed are chosen. Furthermore, only one DC, i.e. node 12, is open for reducing fixed cost. Here, the longest route travelling time is 19.9 hours, which is about 2.5 times higher than the solution in Picture 2. Also, the unreliable link from node 1 to 5 is considered and slow vehicles are used due to their low transportation cost per kilometer (Wang, et al., 2014).

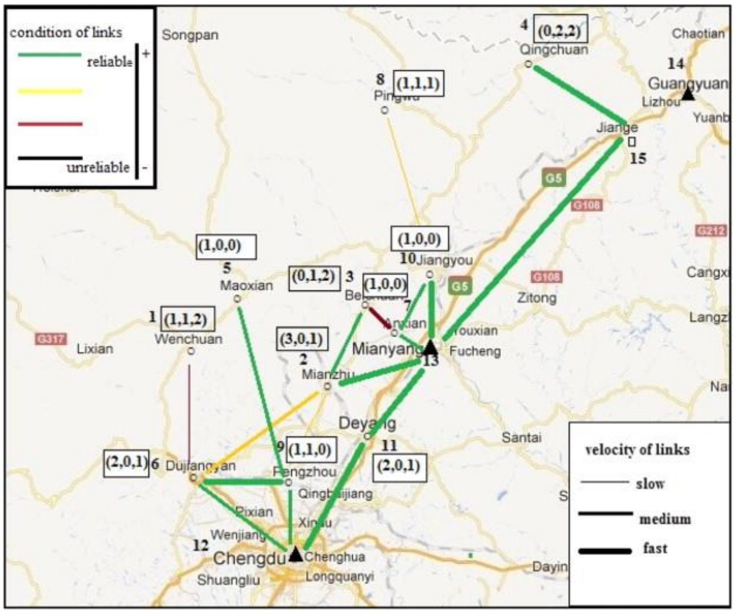
Picture 3: Solution minimization of total cost



(Wang, et al., 2014, p. 175)

Only the solution in Picture 4, i.e. maximization of route reliability, does not use any unreliable link between two nodes. The computed minimum route reliability in this solution is 0.8, whereas in Picture 2 it is 0.45 and in Picture 3 0.36, meaning that distributing relief goods is the safest in this solution (Wang, et al., 2014).

Picture 4: Solution maximization of route reliability



(Wang, et al., 2014, p. 176)

4.5. Distress and cost

In their research papers, Hu and Sheu (2013) and Sheu and Pan (2014) address distress as one of their objectives. Therefore, these articles are reviewed in this section.

- Hu & Sheu (2013): *Post-disaster debris reverse logistics management under psychological cost minimization*
- Sheu & Pan (2014): *A method for designing centralized emergency supply network to respond to large-scale natural disasters*

In the 2008 Wenchuan earthquake in China, approximately 380 million tons of cumulative building waste was produced in the main area at which the disaster happened. In order to make this post-disaster debris useable, recycling technologies and systems should be evolved. Therefore, Hu and Sheu (2013) designed a reverse logistics system for post-disaster debris. They consider several types of debris including human or animal bodies, medical or other waste, debris that is treated first. Dangerous and industrial waste that is, on the one hand, easy to identify but, on the other hand infectious, has to be treated by organizations for specific industrial waste disposal. A third type refers to household waste, which can be managed by normal disposal systems. Commodities, appliances and cars can also be processed by normal disposal systems, if it is possible after consultation with their owners. The fifth type of debris the authors consider refers to building bricks enclosed in collapsed buildings and in those to be demolished. These bricks can be reused directly for constructing new buildings. The last type is comprised of large pieces of fabric, steel bars, plastic and wood components, which should be recycled at the beginning, since this waste can easily be cut into pieces and transported and reused. Each type of debris must be classified and selected regarding priority of reuse, collection or disposal and eventually has to be transported, sorted and reprocessed. Hu and Sheu (2013) address these logistical problems. The model of post-disaster debris reverse logistics system (PDDRLS) consists of four stages, in particular processing of on-site debris (stage 1), temporary site debris (stage 2), mass and advanced debris (stage 3) and reproduction of construction products (stage 4) forming a circulation as soon as recycled aggregated are included in the process of reproduction (stage 4) transporting material again to the disaster area. For this model, Hu and Sheu (2013) consider three objective functions:

- F_1: minimization of costs
- F_2: minimization of risk penalty
- F_3: minimization of psychological costs

Costs are composed of total cost of sorting and grading, total transportation cost as well as storage cost, disposal cost and potential revenue. Revenue can be generated from recycling and reuse in the reproduction process. Regarding minimization of risk, nine penalties are evolved, i.e. risk associated with (Hu & Sheu, 2013):

- exposure to uncollected debris
- storage at disaster site
- storage at temporary site
- storage at debris processing center
- treatment at disaster site
- treatment at temporary site
- treatment at mass debris processing center
- the vehicular collection of debris
- the vehicular distribution of aggregates

As a third objective, psychological costs are considered, due to the fact that after a disaster, debris, collapsed buildings and ruined infrastructure lead to negative emotions. These emotions may also have influence on the rescuer and workers in the debris process, and this is why nine psychological aspects are taken into account, such as waiting time and the already-mentioned subjects with negative emotions as victims or participants in the recovery operations (Hu & Sheu, 2013).

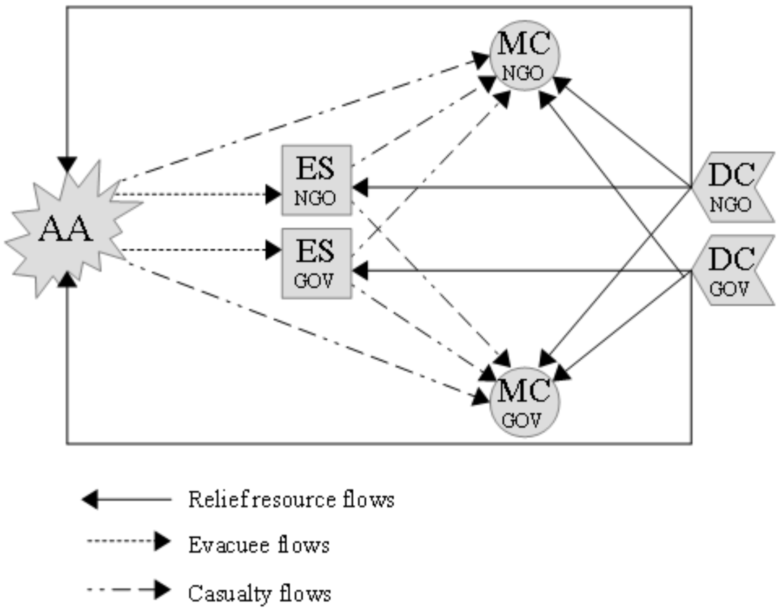
Since the problem is of high complexity, six different scenarios are tested, by which in the first three tested instances, the problem is solved as a single-objective problem by minimizing each of the objectives separately. Moreover, a sensitivity analysis regarding treatment and transportation capacities is made, psychological effects of temporary site are investigated, and a Pareto analysis is done. Analysis of results leads to the following generalized results: a reduction of approximately 23 percent of risk-induced costs leads to an increase of logistical costs by 95 percent. Similar results can be seen when reducing psychological costs by 23 percent, logistical costs increase by 86 percent. Results show that minimization of psychological costs has as a consequence that treatment, transportation and other processes considering debris at stages 1 to 3 are completed in the first thirteen months after a disaster stroke. Therefore, the authors propose using time-varying capacity configurations of debris processing resources and note that additional resources should be available in the early steps. With an increase of storage capacity, risk-induced and psychological costs reduce; hence, the authors make the recommendation to use all capacities available at the first stage. Also, debris with the consequence of negative emotions should be transported to temporary storage sites, although construction has a huge cost on individual workers. Regarding Pareto analysis, it can be said that with a varying risk tolerance level of zero to 25 per cent, the Pareto front of logistical and psychological costs differs only a little, which makes the choice for a decision easier (Hu & Sheu, 2013).

Sheu and Pan (2014) developed a three-stage mixed-integer programming model for designing a centralized emergency supply network for supporting operations in the response phase of a disaster. This model can be used in a developed or advanced country with a basic infrastructure and buildings where emergency activities can be executed. Furthermore, host government and local non-governmental organizations (NGOs) should collaborate rather than working on their own. The three sub-networks should be integrated in a centralized emergency supply network. The three stages are composed of three dependent sub-networks, i.e. shelter network, medical network and distribution network. Results from the first stage are input parameters for the second and third stage, and results from second stage also build parameters for the last stage. Each stage minimizes three objectives (Sheu & Pan, 2014):

- F_1: minimization of travel distance
- F_2: minimization of operational costs
- F_3: minimization of psychological costs

For a better understanding of the network and the calculation of travel distance, Figure 6 shows the structure of the emergency supply network:

Figure 6: Structure of centralized emergency supply network



AA = Affected Area; ES = Emergency Shelter; MC = Medical Center; DC = Distribution Center; NGO = facilities supplied by local non-governmental organizations; GOV = facilities supplied by host government

Own illustration based on (Sheu & Pan, 2014, p. 288)

Since the most important aspect is minimizing psychological costs, the first stage is the development of a shelter network to reduce suffering. In this stage, locations of shelters and routes from the affected area to these shelters are determined. When an early warning system shows that, for instance, a hurricane is approaching, the host government evacuates the affected area and appropriate shelters and routes are defined. Travel distance in this stage is composed of the total distance traveled by victims from the disaster zone to shelters, pictured as *Evacuee flows* with spotted arrows in Figure 6. Operational costs are labor costs of affected areas and shelters as well as fixed costs in the context of shelters. Psychological costs in this sense are costs for concerned people who stay in the area and of people who are already evacuated as well as people who are in the evacuee flows. The second stage attends the medical network to give medical treatment to the victims. Results from stage one are taken, and again, location of the medical centers (MC) is chosen and routes from the affected area to the MCs as well as from shelters to the MCs are identified. F_1 is again the total traveled distance from the affected area to MCs and from shelters to MCs, depicted as *Casualty flows* in Figure 2. F_2 calculates operational costs regarding MCs and F_3 computes psychological costs including costs for victims in MCs, their relatives in affected areas and MCs and victims in the flow from the affected area and shelters to MCs. The last stage designs a distribution network for transporting relief goods. Again, location is determined with respect to results from the first and second stages of the model. Routes are developed from the DC to MCs, shelters and the affected area. Relief commodities to shelter and people in the affected area are delivered and also needed goods for medical treatment are transported to the MCs. Here, F_1 indicates total travel distance from DCs to MCs, emergency shelters (ES) and the affected area, pictured as normal arrows in Figure 6. F_2 calculates total operational costs, consisting of labor cost and fixed cost, and F_3 works out psychological costs of the demand side, i.e. costs for insufficient supply for people in affected areas, ESs and MCs (Sheu & Pan, 2014).

The authors assume, as can be seen in Figure 6, a one-way flow model, since it makes the model simpler, a good condition for the complexity of a large-scale disaster. Furthermore, victims who left the disaster zone and arrive in ESs or in MCs do not return until the end of response phase. Vehicles may load off their demand and must not immediately return to the DC to reload. Respective costs are included in the calculation of fixed costs of emergency facilities. In their model test, the authors investigate a decentralized condition and assume that no cooperative work exists between host government and local NGOs, i.e. they operate independently. Results show that the value of the objective function is significantly better in a centralized condition, particularly for the design of the distribution network. Besides, the centralized network shows a simpler structure of the network. In seven tested scenarios, the following findings are made. If the number of injured people varies, the shelter network does not need to be changed, in contrast to the medical and distribution networks that have to be adjusted. If the number of evacuees increases, more shelters are needed, and the shelter network has to be changed, resulting in a corresponding change of medical and distribution networks. If sheltering capacities of possible candidate shelters are adjusted, this has no significant influence on the other sub-networks. Thus, increasing this capacity improves all objectives for the shelter network but reducing capacity leads to worse objective function values. The same holds true for MCs. Considering the quantity of stored relief commodities, it can be said that increasing this quantity in possible DCs does not improve objective function values for the distribution network, hence, stored relief goods should be sustained (Sheu & Pan, 2014).

4.6. Literature with at least four attributes

Selected articles dealing with at least four different attributes are reviewed in the following part, containing:

- Ortuno, M. et al. (2011): *A lexicographical goal programming based decision support system for logisitics of Humanitarian Aid*
- Vitoriano, B. et al. (2011): *A multi-criteria optimization model for humanitarian aid distribution*
- Liberatore, F. et al. (2014): *A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics*

These articles are related to each other and are reviwed in the order of publication.

Ortuno et al. (2011) establish a Humanitarian Aid Distribution System (HADS), which is a lexicographical GP based decision support system. According to the authors, further improvements can be made easily and also more functionalities can be implemented quickly. In this system, the storage of logistic maps is included, because when a disaster strikes, it means reducing time to modify the system, a very crucial factor in disaster relief. HADS puts its focus on transportation problems and is easy to access and use, even for users with no experience. This fact is a very important one for developing countries, since the population has not the capacity and resources of those in developed countries. The output of the system shows vehicle routes and distribution of loads for each type of vehicle. More precisely, HADS generates routes among nodes with either supply or required demand and chooses adequate vehicles for transporting efficiently under the consideration of other criteria. Hard constraints refer to constraints for load flow and limit, vehicle flow and availability, load-vehicle relation, sub-cycle elimination, budget and vehicle-use relation. The main objective is to deliver the planned amount of relief goods best possible. If this aim can't be met, the priority is to deliver the largest possible amount of goods to each target. Therefore, the objectives of the model are the following (Ortuno, et al., 2011):

- F_1: maximization of coverage
- F_2: minimization of penalization of deviational variables

Six optional goals can be achieved:

- Adjusting cost
- Adjusting travel time of load to a target
- Equity
- Priority
- Reliability
- Security

Cost is not the most crucial factor in humanitarian relief; nevertheless, it cannot be neglected either. Since it is of high importance to react quickly, time of operation, i.e. the maximum time to reach a demand point, is included in the model. Equity must be considered, due to the fact that without this attribute, only close regions and areas that are easy to reach will be preferred. The authors measure equity as maximum deviation proportional to demands. Priority measures proportion of satisfied demand in a specific node and reliability takes account of uncertain damage in infrastructure due to the disaster of aftermaths. It is the probability that the model performs successfully if something unforeseen happens, for instance if a road is not passable any more or bridges are destroyed. The last attribute – security – tries to use routes that are as safe as possible. The assumption regarding security is that a vehicle driving alone is more likely to be attacked by people than a convoy. The more vehicles in a convoy, the safer the route. For solving, the goal is to satisfy several goals, depending on the decision makers' choice, who also defines target values (Ortuno, et al., 2011).

Due to possible prioritization of decision makers, a lexicographical GP model, another approach for the already described GP method, is used for solving the optimization problem in two phases. To optimize the main objective function is likely to be impossible, because of availability of vehicles and budget defined as hard constraints. Hence, the system tries to fulfill the main objective as much as possible, meaning that as many goods as possible are delivered. This goal is preferred to all other goals, resulting in a model with two levels of priority and a lexicographical priority between this objective and all other goals. The second level of the model includes the six mentioned attributes and tries to minimize deviation to target values in order to penalize high deviation. This penalization takes place according to the preferences the decision maker set for different attributes. This step results in the objective function of the second level, i.e. minimize the weighted sum of deviational variables (Ortuno, et al., 2011).

The authors took the situation of Niger in the years 2005 and 2006 to test their decision support model. During this period, Niger suffered a food crisis caused by a too early end of rain in the year before. This food crisis effected about two third of the people in the affected regions. Results were damage to pasture areas, high food prices and therefore high rate of poverty. In reality, the required food distribution was realized by Caritas Development delivering 500 ton of relief goods for operational costs of approximately € 75,000. The logistics map included seven cities (two depots, two intermediate nodes and two demanding zones) and eleven links between these cities. The distance for each link is known, parameters of average velocity, ransack probability and the status of roads are estimated. The authors solved the same case with their proposed HADS. When trying to reach a single target, it seems to be clear that all other targets result in a pretty bad solution. If for example the minimum reachable cost of approximately € 63,000 is met, the total delivering time is twice as long as if the minimum delivering time is taken. Though, costs ascend to € 78,000. So, according to the users' priority and available costs, decision makers can decide if they want to invest less money and have for example more delivery time as well as ransack probability or if they want to invest more money with the consequence of less time to deliver relief goods in demand regions (Ortuno, et al., 2011).

Vitoriano, et al. (2011) extended this preliminary model, propose an approach for measuring several attributes and introduce a linear programming (LP) model to compute them. The goal of the model is to generate routes for adequate vehicles of different types, to transport a fixed amount of relief goods of the same type. Therefore, different criteria or a combination can be used to give direction to the search process (Vitoriano, et al., 2011).

The model consists of one load flow model and one vehicle flow model and the relation between these two network flow models. Constraints are generated considering load flow, vehicle flow including elimination of sub-cycles, and the connection of both, as well as constraints with respect to budget. The following attributes are considered in the proposed model, equal to attributes in the already mentioned previous article Ortuno et al. (2011):

- Cost
- Time
- Equity
- Priority
- Reliability
- Security

A GP model is used for solving the optimization problem and for each attribute, a target value is defined by the decision maker. Since it is not possible to reach every target value, the objective is to minimize deviation, which will be penalized. The higher deviation from a target value to the computed value, the higher is penalization. Therefore, the solution of the model aims to be as close as possible to the set target values, making deviation as small as possible and, therefore, minimizing the objective function, i.e.

$$\sum_{v} \frac{\propto_v}{t_v} DV_v$$

with $t_v \neq 0$, t_v for the target values of each attribute, DV_v for the deviational variables and $\propto_v$ for the weight of importance. Therefore, the objective function of the proposed model denotes as (Vitoriano, et al., 2011):

- F_1: minimization of penalization of deviational variables

The authors applied the model to the Haiti catastrophic earthquake in 2010, since many roads were damaged and many people were concerned. The network includes 24 nodes, three depots and 12 intermediate nodes, delivers 150 tons of relief goods with 300 vehicles always driving together when using the same arc, and needs a budget of 80,000 dollars. Each attribute is considered separately, i.e. its objective corresponds to the optimal solution, resulting in a pay-off matrix showing the conflict between attributes. Results show that when costs are minimized, relief goods are delivered only to the closest nodes to depots. If only equity is considered, all nodes are visited and 60 per cent of required demand is fulfilled. In both solutions, unsafe routes are used, i.e. arcs that are not included when maximizing reliability. But then some nodes remain again unvisited. Another computed solution includes all attributes with equal weights, whereby all nodes are delivered, most unsteady arcs are neglected and acceptable values for all other attributes are attained. Also, only the fastest vehicles take the longest arcs and, therefore, operation time is rather close to optimality, a fact that is part of every solution with a nonzero time weight (Vitoriano, et al., 2011).

Liberatore et al. (2014) again extended the model by Vitoriano et al. (2011) in the article *A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics*. There, a RecHADS model is proposed, where HADS stands for Humanitarian Aid Distribution System and Rec is the algorithm. The authors focused on plans for recovery of destroyed elements in an advanced response phase as a consequence of a disaster or its aftermath. With this system, arcs that should be recovered due to damage are identified. Since in Haiti 2010 the airport was destroyed, the port was ruined and bridges and roads were no longer passable, the authors tested their model on this case. Their infrastructure recovery model aims to handle such situations and optimizes recovery plans for destroyed elements for supporting the following distribution operations (Liberatore, et al., 2014).

Again, deviation from target values should be minimized and an uncapacitated commodity flow model with proportionality constraints is generated, combining several attributes. The development is the implemented recovery model, where a set of destroyed arcs is defined. These arcs are not passable and need to be repaired in order to be used. This step of reparation requires investments such as equipment and people who repair damaged arcs. This recovery process is linked with costs and ends with the complete restoration which makes the arc fully usable again. A budget for recovery is given and must not be exceeded. Before recovery takes place, it may be possible that some nodes are not reachable at all and excluded after a disaster strikes, a situation that is not unlikely. As a consequence, maximum demand must be adapted, since it is not possible to reach zones that have no connection to suppliers and, therefore, demand depends on the set of undamaged and recovered arcs (Liberatore, et al., 2014).

Their proposed hierarchical model is a three-level lexicographical model with the highest priority to help as many people as possible. Therefore, the following levels are included (Liberatore, et al., 2014):

- F_1: maximization of coverage
- F_2: minimization of infinity norm distances
- F_3: minimization of the norm distances

As soon as delivery flow of maximal demand is fixed, the model takes into account the following other attributes with the goal of determining the best combination by computing the pay-off matrix, optimizing each attribute:

- Cost
- Delivery time
- Security
- Reliability

With these attributes, the relationship of different attributes becomes clearer and with this matrix, ideal and anti-ideal points can be defined, representing the maximum and minimum obtainable values for the considered attributes. Following, a CP approach solves the second and third level and for solving F_2 it aims to finding the minimized maximum distance from attributes to their best value. At last, F_3 is solved to get the plan for recovery and the distribution of best compromise solution with respect to attributes (Liberatore, et al., 2014).

Again, the model is applied to the case of Haiti 2010 with 24 nodes and 42 arcs, where 12 are damaged arcs and one node is completely isolated from the network after the disaster struck. Damaged arcs are those with a reliability of less than or equal to 45per cent. The served demand is 220 if none of the destroyed arcs can be recovered; if one arc is recovered, it rises up to 250, which is equal to the total demand. This is because demand of the excluded node is equal to 30 and as soon as this arc is repaired, the whole demand can be delivered. Findings show that not all arcs have to be recovered for obtaining the best values for the attributes. Also interesting is the distance between ideal and anti-ideal points, since this represents the range of possible solutions and shows the impact on each attribute when budget is increased. For testing the effect of a recovery budget increase, the third level of the approach is solved with equal weights for the attributes. With the resulting information of how many arcs can be recovered and the values of attributes, the decision maker can make the decision of how high the investment in recovery operations should be. If six arcs can be repaired, the best compromise solution can be generated. As such, even if some attributes are worsened, a better overall solution can be reached (Liberatore, et al., 2014).

Finally, the authors compare sequential versus coordinated optimization, since it is likely that recovery and distribution operations are realized by different organizations with just a little or even no coordination at all. For proving that it would be a loss if organizations do not coordinate, i.e. operations for recovery and distribution are carried out separately, the authors solve again the first step of the lexicographical approach. After that, the value of the variables is fixed to the corresponding optimal solution. The solution tries only to connect all necessary demand nodes to supply nodes and does not further improve this solution in the next phase. Without the constraint for the recovery model, they continue and solve phase 2 to compute the pay-off matrix as well as ideal and anti-ideal points. These results are optimized as well as phase 3, but again without recovery model constraint (Liberatore, et al., 2014).

When comparing the two solutions, findings are made when analyzing the following adapted Table, in which negative signs refer to the situations in which the sequential solution dominates the coordinated solution:

Table 3: Gaps (%) between sequential problem & coordinated problem solution attributes

Disconnected nodes	rb	G_{TX}	G_{PX}	G_{PG}	G_{RMN}	G_{RG}	solution gap
1 node	1	3.64	0.00	4.41	0.00	0.00	1.61
2 nodes	1	0.92	0.00	8.33	0.00	0.00	1.85
	2	0.00	0.00	6.81	0.00	0.00	1.36
3 nodes	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.88	50.00	18.79	0.00	**-3.50**	13.24
	3	**-2.65**	50.00	19.88	0.00	19.58	17.36
4 nodes	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	7.62	0.00	7.81	0.00	15.97	6.28
	3	7.62	0.00	7.97	0.00	15.97	6.31
	4	7.62	50.00	26.09	0.00	20.17	20.77

TX=Maximum arrival time; DX=total served demand; PX=maximum ransack probability in the distribution plan; PG=Global security measure; RMN=Minimum used arc reliability in the distribution plan; RG=global reliability measure; rb= recovery budget

Adapted table based on (Liberatore, et al., 2014, p. 12)

When one node is disconnected, the overall compromise improvement is 1.61 per cent, even though regarding reliability and maximum security, the sequential model is as good as coordinated model. Nevertheless, in all other aspects, the coordinated model dominates the sequential model. Similarly, when two or four nodes are disconnected, coordinated optimization is better in all aspects and dominates sequential optimization. Only when three nodes are disconnected does sequential optimization dominate in two aspects (Liberatore, et al., 2014).

Considering three disconnected nodes, the authors provide the following analysis in which SM stands for sequential model:

> *"When two nodes are disconnected (...) the solutions found by RecHADS dominate those of SM. This is not the case in the instance with three isolated nodes (...). In fact, when rb=1 the SM solution has a better global reliability, and when rb=2 the distribution time is slightly better."*
>
> (Liberatore, et al., 2014, p. 12)

According to the authors, when the recovery budget is set to 1, the sequential solution dominates regarding global reliability, and if it is set to 2, a better distribution time results. When three nodes are disconnected, the presented Table in their research paper shows a negative sign when rb=2 at global reliability measure and if rb=3 at distribution time. This fact does not disprove the fact that the coordinated model dominates that sequential model; nevertheless, it should be mentioned.

In addition, Table 3 shows that the more nodes are disconnected, the better is the solution from the coordinated method compared to the sequential model. So, the more nodes are disconnected, the better it is to use the coordinated method - and after a disaster strikes, it is likely that the situation is complex rather than easy to handle. Although not all solutions dominate sequential ones, an overall improvement can clearly be seen and justifies the use of the more complex model, since the recovery constraint is considered and complicates the model (Liberatore, et al., 2014).

5. Interviews

In the course of this Master's Thesis, two interviews were conducted in order to examine if theoretical models and practical implications are consistent. The interview partners were Ing. Mag. Klaus T. Jäger, ObstdG, Austrian Armed Forces and Ing. Alexander Gratz, BA, Head of disaster emergency service of the Vienna Red Cross. With these interview partners, both governmental and private emergency relief are considered.

Regarding the Vienna Red Cross, it first has to be mentioned that, according to Mr. Gratz, Vienna is exceptional compared to the other federal states of Austria, because the City of Vienna has two municipal departments, the Magistratsabteilung (MA) 68 Fire Services and Disaster Relief and the MA 70 Ambulance Service. Nevertheless, Vienna considers the same units as the other federal states in order to be compatible. In their disaster relief service, they have search dogs, water treatment technicians, a special unit for accommodation, care and camp, a chemical-biological-radioactive-nuclear (CBRN)-unit with experts, especially for the self-protection of employees. This unit also advises how to act in the event of epidemics and pandemics. The Vienna Red Cross also has a telecommunication service with which communication can be guaranteed even in the case of blackout, so they are autarchic. Furthermore, they have a standby logistics unit so that everything needed is always available. Cooks build their unit of food-service, though, as already mentioned, one of the units is accommodation, care and camp and this is the reason cooks are needed. Another unit is support for technology, helping in issues about electricity and thermal energy. All of these units are financed through donations, which is the most crucial difference considering governmental and private disaster relief. The Red Cross trains their employees and managers and have their own emergency training. This education must be adapted to the overall conditions, supported and further developed (Ing. Alexander Gratz, 2016).

Considering Austrian Armed Forces, there exists an own headquarter for emergencies, called AFDRU (Austrian Forces Disaster Relief Unit). If a disaster strikes, a Command Staff of the Armed Forces starts, plotting the effects. One effect might be a direct, immediate impact on Austria or an indirect one so that the country is able to help abroad. On the international level, there is a committee through which demand can be registered. This demand could be covered by many different nations and organizations and the users decide which country they want to have for which need. For instance, Austria should be responsible for drinking water treatment, the Germans should take care of field hospitals and the Americans should arrange supply of equipment, medication and bandaging material. So, this is completely different for every disaster. There exists a situation center that is constantly occupied and people there also plot media information. They are connected internationally and alert the chief of general staff when a certain level of alert is reached. The chief of general staff would alert the Federal Minister of Defense and Sports who again would report to the federal government, although this depends on the extent of the disaster. Many things are coordinated by the Federal Ministry of the Interior as, for example, a coordination platform consisting of the Federal Ministry of the Interior, the Federal Ministry for Transport, Innovation and Technology, the Federal Ministry of Health and Women's Affairs and as required the Austrian Federal Railway, the Austrian Red Cross, Caritas, MA 70 and the Austrian Armed Forces. On this platform, coordination takes places from twice a day to every two weeks and it is decided how to continue in a disaster situation. It must be mentioned that this has only coordination competence and no decision-making competence. If the Federal Ministry of the Interior gives an order, the Austrian Red Cross has to establish a hospital (Ing. Mag. Klaus T. Jäger, 2016).

5.1. Preparedness

Before a disaster happens, preparations must be made. The Austrian Red Cross had to decide between the following two approaches when considering logistics: buying services and not having any means of transportation or having a minimum fleet and being able to manage the first phase in a disaster on its own. They decided for the latter and now possess one 26-ton truck, one 7-ton truck and some other vehicles, i.e. panel trucks and flatbed trucks and thus, the specified performance parameters can be met in the first phase and demand can be transported and delivered. Performance parameters depend on the scenario and therefore, they are different according to the type of disaster. The highest priority is to safe as many people as possible, no matter what the disaster type is. Once the Austrian red Cross has to provide shelter, another time they have to take as many people as possible under a physician's care. Obviously, this is a high and important cost factor, the Austrian Armed Forces must not consider. Trucks of the Vienna Red Cross are not loaded in advance and in the case of an alert, the decision which goods to load must be made quickly. In Vienna and of course in Austria, there are several storage places at which aggregates, tents and camp beds are stored in order to shelter a hundred people self-sufficiently for a period of a few days. In other words, one hundred people can be accommodated in heated tents with electricity. This equipment is immediately available and loaded within thirty minutes. Everything is already on trolleys and pallets and, therefore, mobile. Distances are very short, and an elementary factor is that also supporting staff can load these trucks. So logistically, they work on a trailer basis considering accommodation and care, simply because this is the cheapest option. There are no major repair and maintenance costs, several trailers are loaded and people trained. To accommodate one hundred people, a truck is needed to transport everything they need. There exist different tactics: in one scenario, helpers get this trailer to the location where material is needed within a given time, usually one hour. Helpers supply the labeled goods, and qualified employees also get to the place and work with their material. In case a minimum of material is needed, for instance if people must be accommodated in a school or a hall, the truck with its own material is not needed in the first place. Trailers with camp beds, desks and benches are brought there, a minimum stock of food and drinks for providing people really one hour after the alert. Then, it is decided whether people have to sleep there, external toilets or showers are needed and what else has to be adapted in order to accommodate people appropriately. The main and primary goal is that people do not find themselves on the streets. The control center is the operative element and the main inspection officer either sits in the control center or is on site and decides whether more or fewer units are needed or the point in time when units should be replaced. These optimization decisions happen through a manager in the leadership cycle (Ing. Alexander Gratz, 2016).

For these situations, articles reviewed in chapter *4.1 Coverage and cost* by Barzinpour & Esmaeili (2014) and Esmaeili & Barzinpour (2014) could be relevant. Here, coverage as well as cost factors are considered. Probably, one out of three objectives in Barzinpour & Esmaeili (2014) is not of high importance for the Austrian Red Cross, i.e. facility setup costs. Austria has a very good infrastructure and problems as the authors described in their example of an earthquake in Iran are not as big in Austria. Since not that many disasters happen in Austria, minimizing equipment holding costs and total transportation costs, as in objective F_3 in the article, is the one with higher priorization. Nevertheless, all three objectives by Esmaeili & Barzinpour (2014), i.e. maximization of covered demand inside the local region, minimization of total facility set-up costs, tactical and operational costs as well as maximization of percentage of covered demand outside the local region could be relevant for the preparedness of disaster relief the Austrian Red Cross.

Coming back to the interview, if for example a big accident happened with two busses and sixty injured people, the control center of the Austrian Red Cross would be able to cover this. If a long-term crisis such as the refugee crisis in the year 2015 occurs, a crisis committee will be established. Clearly, this team is not able to start working within an hour but takes a couple of hours to get productive. They must become acquainted with the situation and then, decision-making bases for the chief of operations can be developed (Ing. Alexander Gratz, 2016).

5.2. Response

Let us look again at the Austrian Armed Forces and the example that Austria is responsible for drinking water treatment after a disaster strikes. The mission here starts with an alert followed by a very short formation, because application engineering is already finished. This means that troops are already vaccinated and have world-wide vaccine immune protection. Everybody has his or her equipment at home and at best already packed a container with personal equipment and the equipment needed for the mission. In this example, equipment would contain a drinking water treatment plant. For self-sufficiency, tents, rations, radio equipment for communication, implements for enlarged self-help as well as help for colleagues are needed. Furthermore, rescue and recovery elements could be required. This equipment is already packed, brought together and either taken to the disaster area by airplanes, which the Austrian Armed Forces own, with rented planes, with trucks on the road or trains on the rail, depending on how far away the place of operation is and the fastest way to get there. Before getting there, explorations are made which can be done anytime and are done regularly. Aerial photographs and satellite pictures of roads are used. After a disaster has occurred, one has to consider that for instance bridges may be destroyed or that streets are not passable anymore. If extensive transports are necessary and whole factories have to be transported, the entire route is driven by a small vehicle, because big vehicles probably may not pass the bridges. The other option is to optimize the transportation route, i.e. find another route where no bridges have to be passed. If this is not possible, bridges must be strengthened. Pioneer forces have the ability to decide how heavy vehicles can be for safe passing. Another decision may be that vehicles are only allowed to pass in one direction and a military unit blocks oncoming traffic. If the bridge must be reinforced, pioneers will strengthen it so that vehicles can drive over with all needed elements. According to Mister Jäger, this is optimized. There exist also maps with information on which bridge can withstand which weight either in both directions simultaneously or in a one-way system. So, this information is available in advance (Ing. Mag. Klaus T. Jäger, 2016).

This information corresponds with literature about reliability, as for example in chapter *4.4 Response time, reliability and cost*. Here, Wang, et al. (2014) also take the objective of route reliability into account. Although for the Austrian Armed Forces, the objective of total cost minimization is not as relevant as in the literature, minimization of maximum route time and reliability are considered. Wang, et al. (2014) don't neglect the possibility that routes and bridges may not be passable anymore, which is also a key factor in practice, as Mr. Jäger told. Most up to date maps are nessecary for the objective of minimizing route time. The better immediately available information, the better is disaster relief optimzation in real life. Also, Ortuno, et al. (2011) established a HADS extended by Vitoriano, et al. (2011) as well as Liberatore, et al. (2014). These articles are reviewed in chapter *4.6 Literaturen with at least four attributes*. The model already includes storage of logistic maps and recognize the importance of a quick availability with the consequence of reducing time. The output of this model shows routes as well as load distibution already depending on the type of vehicle.

There are also early-warning systems in Austria, with which the weather is constantly plotted, and during a mission, once or twice a week weather briefing takes place at which it is checked whether roads are passable or not. If, for instance, the mission is in the rainy season in the Republic of Mali, transportation takes ten times longer than usual. Also, weather briefings include information about flight data and decisions about whether a helicopter can start or if it would be impacted by ice. These facts always must be considered and analyzed before starting a mission and any transport. Information is always up to date. Before going to Haiti, an overview of the situation is made with all medical challenges medicines will have to face, for example poisonous snakes or mosquitoes spreading the Zika virus. Also, the decision about whether to go somewhere by plane needs information in advance, such as if a plane can still land near the disaster area after all. For a successful mission, a crucial factor is updated information which works very well regarding the missions of the Austrian Armed Forces. The answer to the question if needed information for operation is sufficient was “yes”. Of course, there is a difference between needed and available information. Available information is the number of pioneers, which radio equipment there is and how far away the affected area is. Then, there is the knowledge one should have for making good decisions. If this difference, i.e. delta, is too big, reconnaissance must be done. This can be internet research as well as an exploration team. According to Mr. Jäger, one will never know everything. As a result, decisions are made on the base of assumptions (Ing. Mag. Klaus T. Jäger, 2016).

Although every country has its own core task and the primary task would be drinking water treatment, the Austrian Armed Forces also are capable of reconstruction and first aid as for instance in the case of the Tsunami eleven years ago. So, if a sick child, a pregnant woman or a pioneer from another country needs help, medical aid is of course provided for local victims, even though medical treatment is the main task of an organization from another country (Ing. Mag. Klaus T. Jäger, 2016).

For both, the Austrian Red Cross and the Austrian Armed Forces, emergency plans exist and are followed. Nevertheless, they must be fitted with respect to the current situation. If there is a joint effort between the Austrian Armed Forces and the Austrian Red Cross, the Federal Ministry of the Interior or the MA 70, there exists a platform upon which parallel structures are exploited. Every organization has its own alert and its own emergency plans ((Ing. Alexander Gratz, 2016) and (Ing. Mag. Klaus T. Jäger, 2016)).

Looking at the Vienna Red Cross, there exists a standard process, a plan of action for Vienna, at which different criteria that can occur in a disaster situation are written down. Depending on the scenario, the 24/7 occupied headquarter warns the corresponding rescue workers as well as disaster relief workers, i.e. the specialists. Usually, there is an official chief of operations; the Vienna Red Cross is alerted afterwards and told what to do. This alert arrives in the headquarter and is designed in a way that everything has to happen quickly, especially when thinking about blackout, in which only thirty minutes are left to use the telephone networks and send short messages. In this case, a fast, initial reaction is essential and that is why decisions are made without requesting and considering the management by the headquarter. They take the plan of action, and if for instance, a house collapsed, and a number of x people is injured, they exactly know which units to alert, do so and these units join up or they are only pre-warned so that they know that they should get ready or move to the defined station. There is an officer on duty, analogous to the fire department. This is a person who represents the commander-in-chief, who is the highest commander. He or she is accessible 24 hours a day, 7 days a week and has decision making authority. Usually, this initial alert will never be perfect in a catastrophe scenario. However, this alert is made and then the situation as well as management procedure must be satisfied, i.e. evaluate, execute, examine, improve. This is what managers of the Red Cross learn and have learned in a long training. No plan can cover what happens next (Ing. Alexander Gratz, 2016).

Such a problem is reviewed in Chang, et al. (2014) explaining the emergency logistics scheduling problem where input data is available and used and each demand point consists of certain information. This could be interpreted as the plan of action, Mr. Gratz described. In the emergency center, plans are designed, this is part of the article by Chang, et al. (2014) as well as the statement of the interview partner. After the last needed decisions, the final routing schedule is developed. Also, in this case, literature and practice are in agreement.

The answer to the question of the most important goal was in both interviews the same, i.e. saving people's lives. Mr. Gratz of the Vienna Red Cross stated that their focus is first to help the most vulnerable people. It cannot be said whether the goal is to get people out of the disaster area as quickly as possible, because this depends on the situation. If a mudflow (one of the most probable scenarios in Austria after a high flood) in a very small Tyrolean side valley occurs, in general, this does not hit people very hard. People there have food and drinks for more than a week at home, some even heat with an oven and they do not have a big problem if no infrastructure exists for two weeks. Even in the case of floods it is not necessarily the most important objective to get people out of the disaster area. As long as water stays behind the protective barriers, people live their lives - as in Picture 5 taken a few

Picture 5: Danube high water, Wachau 2013

years ago, where one can see that the Danube is sealed off with protection barriers and next to it, a man stands mowing his lawn (ORF, 2013). So, objectives depend on the current situation. Mr. Jäger highlighted the so called “Golden Hours” or “Six Hours” when it comes to optimization of maintenance of victims. In case of an earthquake or the collapse of a building, a high degree of readiness is crucial and AFDRU with search dogs or rescue teams must be on site very quickly. If capacities and resources are restricted, people with the greatest survival probability will be rescued first. During the interview in a Vienna café, Mr. Jäger offered an example: If an incident happens, and Mr. Jäger and I had an open bowel escape and those at the neighboring table had a cut injury on the upper arm and bled as a result, they will be treated first and we will be the unlucky ones. We would probably need two doctors and three critical care paramedics for six hours while twenty other people with splinter injuries can be saved. If someone has a slight injury and is panicked because he has never seen blood, one leaves him or her alone, because he or she has no life-threatening injury. The answer to the question of which area to enter first after a tsunami when some areas are more difficult to reach than others was the following: The basis of valuation is where the risk is the least. If there is a landslide in a mining area and simultaneously a landslide where the population is waiting for us, the priority is the area with people and no mines. The early warning system for weather conditions is relevant in practice. If it is known that there will be avalanches in winter, avalanche units are prepared, and they have everything packed, starting with complete avalanche equipment to ski, avalanche transceiver and an avalanche probe. In short, there is always a reaction to weather and, therefore, equipment can be used more quickly ((Ing. Alexander Gratz, 2016) and (Ing. Mag. Klaus T. Jäger, 2016)).

5.3. Costs

When it comes to the question of how costs are considered, the answers could not have been more different. For the Red Cross, this is a difficult topic. In some federal states, a disaster is proclaimed (Ing. Alexander Gratz, 2016). In Vienna, the act of the Vienna disaster relief and crisis management (Wiener Katastrophenhilfe- und Krisenmanagementgesetz – W-KKG) applies whereby a disaster is defined as follows:

„Als Katastrophe im Sinne dieses Gesetzes ist jedes bereits eingetretene oder noch bevorstehende Ereignis zu verstehen, das durch elementare, technische oder sonstige Auswirkungen geeignet ist, in ungewöhnlichem Ausmaß Personen- oder Sachschäden zu bewirken und das mit örtlichen Einsatzkräften nicht bewältigt werden kann." (§ 2 (1) W-KKG)

According to this act, a disaster is any event which has already occurred or is about to happen, which is properly to cause personal or material damage to an unusual extent due to elementary, technical or other effects and which cannot be overcome by local forces. So, if certain criteria are met, it is a disaster per definition and remuneration is regulated by law:

„Die Kosten für Einsätze gemäß § 2 Abs. 1 bis 3 trägt die Gemeinde, soweit in diesem Gesetz nicht (sic!) anderes bestimmt ist und nicht Einrichtungen oder Organisationen auf Grund einer freiwilligen Zusage oder einer Vereinbarung mit der Gemeinde bzw. auf bundesgesetzlicher Grundlage Leistungen erbringen." (§ 21 (1) W-KKG)

Costs should be borne by the municipality except where express provision is made to the contrary in this act and establishments or organizations perform on a voluntary commitment or on an agreement with the municipality or on the basis of federal law. Nevertheless, this is a complicated issue. Volunteers, especially the specialists of the Vienna Red Cross, do an officers' training with a training period of six to ten years, depending on the quickness. Under ten years of active cooperation and training, it is difficult to know the business. People need equipment and further education and the organization needs a building for training and for storing material. This is associated with enormous costs. This is again different to other federal states, where the Red Cross takes over fixed tasks of the state. Furthermore, there are various funding possibilities.

For the Austrian Armed Forces, costs are completely irrelevant due to the primacy of politics. The main committee of the National Council can decide whether a mission is started or not. Then, the Austrian Armed Forces put it in execution. As usual, there are always exceptions: the first one is if there is a support service, for example for the Federal Ministry for the Interior, then the Austrian Armed Forces performs transportation which has to be financed either by the Federal Ministry for the Interior or a special financing by the Federal Ministry of Finance. If there are regional disasters, for instance a drill slips down a hillside and oil leaks and may pollute groundwater, it is at state level to proclaim a catastrophe and decide that there are not enough civilian resources to overcome the problem. Basically, the Austrian Armed Forces would be a competitor for civilian service providers and this must not be. As a consequence, the national warning center issues an alert, and the Austrian Armed Forces are allowed to be deployed. Then, no costs are charged because it is one of the core competences of the Austrian Armed Forces. Costs are only charged for additional services. If the army receives an order from politics, it has to realize it. Details are up to the Austrian Armed Forces. If costs are considered, it is in the phase of recovery, although reconstruction is not the competence of the Austrian Armed Forces with one exception: if it is a mission with Civil-Military Cooperation (CIMIC). If the decision is made that a school should be reconstructed or a well should be bored, they have to do so, but it has to have a CIMIC background (Ing. Mag. Klaus T. Jäger, 2016). Summarized, it can be said that costs do not have priority or play an important role. Crucial is the order fulfillment in the given time, so reaction time must be optimized.

5.4. Cooperation

Another interesting question in both interviews was if cooperation with international relief organizations, with respect to local organizations, works well. Mr. Jäger of the Austrian Armed Forces sees no problems with international organizations since there are only small points of intersections. He gave an example of post-war Bosnia when international relief agencies of Austria and for instance Caritas or "Saatgut für den Frieden" help. Everyone can come to the Austrian Armed Forces in an emergency or if they need food, shelter or first aid. Food and accommodation would have to be charged. Basically, tasks are different. In this example, the Austrian Armed Forces would be responsible for transporting seed and material for the roof truss. Civil organizations would be responsible for financing a school, so there would be a complete separation. The organization which gives transport decides which goods are delivered to which locations. So, if an organization collects clothes, it decides the percentage of clothes for Bosnians, Croatians and Serbians. Then, the Austrian Armed Forces transports the goods (Ing. Mag. Klaus T. Jäger, 2016). Also, Sheu & Pan (2014) indicate in their article about emergency supply network for supporting operations, that better results can be obtained if organizations cooperate instead of working on their own.

Considering local organizations, the state sees the benefits according to Mr. Jäger. On the one hand, they need the armed forces and, on the other hand, due to international relief organizations, capital flows into the country. Pioneers need to buy food and beverage and, therefore, help the local economy. Competition is barely there, because armed forces cover a different spectrum. There are hardly any civilian organizations entering an area with mines. Of course, there are specialized organizations that take over the task, but this is also pre-coordinated by the army. Mine maps exist and there are different companies that finance the removal of mines in an area but only one coordination with the shared goal to clear the area. Therefore, competition between organizations does not exist, according to Mr. Jäger, but on a personal basis, there may be envy. As long as, for example, the United Nations Development Program (UNDP) is active in Bosnia, there are many jobs. If absolute peace is in the country, employees of UNDP in Sarajevo would not have a job anymore. In Sarajevo, they are close to home and may fly back to Vienna for the weekend. In Sarajevo, employees have a rather good long-term job on the basis of a contract for work that is always extended as long as there is a mission. If the mission ends, they have to apply for another job, for example a mission in Africa, Mali or Crimea; they are one out of seventy candidates. It is all too human that employees prefer a mission in Sarajevo, where they have film festivals, a theater and are in Austria within an hour rather than being in Crimea, when there is still war and the danger of being shot is higher or in Mali with other challenges to cope with. In total, there is internationally no competition or envy. Domestically, there is, according to Mr. Jäger, competition in some areas, not on an operational level, but on a decision-making level for instance between MA 70 and the Red Cross. As already mentioned, MA 70 is responsible for disaster relief operations in Vienna and coordinates Emergency Medical Service, Red Cross, Black Cross and Austrian Workers' Samaritan Foundation. The Red Cross coordinates everything in Austria, except operations in Vienna (Ing. Mag. Klaus T. Jäger, 2016). Considering cooperation between the Red Cross and the Austrian Armed Forces in Austria, Mr. Gratz said that there is no competition at all, but a good collaboration. Furthermore, the army is only allowed to become active according to law and if more than one mission must be accomplished, they have to prioritize. Every governor of an Austrian province and every district commissioner has the possibility of asking the Austrian Armed Forces for help and if too many do so, prioritization must be made. Furthermore, roles are separated. The fire brigades in Lower Austria are the ones clearing the danger zone and the Red Cross together with *Team Austria* supports them and other organizations and the same is true with cooperating with the army (Ing. Alexander Gratz, 2016).

Regarding foreign and domestic missions, it has to be mentioned that the legal process itself is completely different. Furthermore, efficiency has to be considered. The Austrian Armed Forces can, of course, prepare drinking water. If someone calculates the costs of one liter of drinking water including the flight to the affected area, the needed set of equipment and personnel costs, he or she might conclude that lot of mineral water could be bought. Mr. Jäger offered the example that if someone in Ethiopia pays € 50,000, many companies would instantly bring mineral water, without the need of aid organizations or NGOs (Ing. Mag. Klaus T. Jäger, 2016).

5.5. Challenges

Considering problems and challenges, Mr. Jäger mentioned strategic air transport in the context of transport capacity. The Austrian Armed Forces would be able to fly to Africa with three c-130 aircrew training systems, but not more. Strategic air transports could be rented but in the case of a disaster, every nation wants to help and needs their own transportation possibilities. Therefore, transport capacity is a challenge. Also, restricted resources in each area are a problem, such as personnel resources. The requirement is that 1,100 people are abroad per year, and this requirement is fulfilled. Of course, it can also be covered if more persons are needed. These AFDRU-elements are always in the country, air transport capacity is available, 70 hook-loading systems and 29 high-capacity buses for transportation are in-country. A stock of medicines, vaccines and dressing is always available. As a result, there does not exist a problem (Ing. Mag. Klaus T. Jäger, 2016).

According to Mr. Gratz, there are always checks during and after every mission. After the initial alert, everything must happen very quickly. It is always a good idea to take a look on the action plan, if all steps were followed. Also, documentation is important due to possible legal consequences if after evaluation it turns out that a wrong decision was made. Then, the decision maker has to prove which information was available at the time and based on this information, the decision was correct. Not only decisions must be documented but also every operation that is done on a patient. If two options are possible and on the right track a bomb could explode, and the fire brigade said the left track is safe, the decision to go with the left track is correct at that point in time. Documentation is also very important for the potential to improve and the ability to understand when a decision was made based on which information. This will also influence future missions. After every shorter mission, there is a peer-system, i.e. critical incident stress debriefing, in order to talk with colleagues about the mission and its difficulties. With a little more temporary distance, the mission is again evaluated, and it is discussed what was done well and what was done wrong and hopefully, the Vienna Red Cross can learn from it (Ing. Alexander Gratz, 2016).

Mr. Gratz experienced this situation shortly after the earthquake on the Philippine island of Bohol in 2012. There are many blackouts in India or Latin America lasting a few days. But the situation is not comparable to a blackout in Austria. Similarly, in the Philippines, after the earthquake, there was no electricity for weeks. People there live self-sufficiently; they have enough wood for cooking and survive without electricity. They are used to the fact that not everything can be bought every day, especially in poorer regions. In Vienna, it would be a huge problem if no electricity were available for two weeks. Hygienic standards are completely different and will not be able to be met without electricity in Vienna, but it is different in the Philippines. In this circumstance, the issue of resilience becomes important. After the earthquake, churches and buildings collapsed. An info-point was established at which people received the latest news; because internet and phones did not work, at this location, they could get information about where to get help and pick up relief goods. Also, cell phones could be charged at the info-point. The mobile network was one of the first things that worked again, even faster than the electricity grid (Ing. Alexander Gratz, 2016).

5.6. Excursus Blackout

Both interview partners independently mentioned the huge problem of blackout, since this will be a major challenge in the future. In case of a blackout, gates do not open any more, no one is able to get into the building due to the electronic locking system, no light or heating is available and crucial time for helping people is lost. When talking about room for improvement, blackout raises awareness of the Vienna Red Cross. A few years ago, the Vienna Red Cross had only one location in the 3rd district of Vienna, next to one of the biggest cooling houses in Austria. In this cooling house was an ammoniac leakage and the location of the Red Cross was in the danger zone. Luckily, the wind was blowing in the right direction. If the wind had gone in the other direction, forces could not move into the building and most of the needed material would have been in the prohibited area. This was the reason a second location was opened in the 21st district of Vienna and the Vienna Red Cross now is able to operate if a major event happens. In case of a blackout, the location in the 3rd district would be able to continue operating, since a few days of electricity supply is guaranteed. A remaining huge tank of the former owner of the property is now used and an emergency generator is plugged. Therefore, the organizations can act autarchically for a few days, including operations for approximately hundred vehicles. Due to cost concerns, the location in the 21st district of Vienna is autarchic for only seven days at a time. Also, fuel is extremely expensive, since special fuel is needed, because normal fuel is perishable. Many optimization problems are not needed if the issue of blackout is under control, because self-help is not needed, and operations can start immediately (Ing. Alexander Gratz, 2016).

6. Summary and future research

The present thesis treats relevant literature considering multi-objective optimization in disaster management. The article *Multicriteria optimization in humanitarian aid* by Gutjahr and Nolz (2016) provide the basis and thirteen articles shortly reviewed in their paper were picked out and covered in greater detail.

Before starting the literature review, basic information about multi-objective optimization and the mathematical problem formulation are given. Furthermore, all relevant solution methods for the present review are discussed explicitly. Before getting into the main part, i.e. the literature review, humanitarian logistic is introduced, and the different phases of disaster management characterized. Also, relevant objectives in disaster management are different than in other optimization problems and therefore, listed and described. The main part of this thesis starts with an overview of the reviewed articles and explains why they were chosen. Articles must have a minimum ranking in Scimago Lab (2017) to have been shortlisted for this review. After this first selection, the purpose was to offer a good sample of solution methods and their underlying decision making models and considered objectives. Since uncertainty unfortunately plays an important role in disaster management, one chapter is also dedicated to this issue.

In order to get more feeling about the decision making process in disaster management, two interviews were conducted. The first one with Ing. Mag. Klaus T. Jäger, ObstdG, Austrian Armed Forces and the second one with Ing. Alexander Gratz, BA, Head of disaster emergency service of the Vienna Red Cross. These two organizations were chosen to work out the crucial difference between governmental and private emergency relief. One important finding is that this difference couldn't be bigger with respect to budget. In literature, costs are always *"not the most important factor"*, nevertheless they are and must be considered. Of course, cost should not play a very important role when it comes to save lives, but the interview with the Vienna Red Cross clearly showed, why costs must not be neglected in their processes.

Findings show that for the Austrian Armed Forces, models established in the reviewed literature cannot be applied one-to-one. In literature, costs most of the times play a crucial role and surprisingly, Mr. Jäger didn't care about the cost factor that much and was surprised himself that costs play such an important role in literature. Depending on the scenario, organizations need different optimization models in practice and probably, established models in literature cannot be implemented when a disaster strikes. Therefore, organizations need and already have action plans in advance. The first prioritization is, according to the interview partners, always saving lives. Therefore, response time must be minimized in order to get to victims as quick as possible, and coverage must be maximized. For non-governmental organizations, costs do play a role and facility setup costs as well as inventory and operation costs should be as small as possible. Nevertheless, the decision makers prioritize saving lives instead of minimizing costs. What was not answer in the interviews was the question, which solution methods disaster relief organizations use, which may be an interesting topic for future research.

A very important topic in the present time and for the future is and will be the issue of blackout. As we all know, disasters like earthquakes, typhoons, food crises or hurricanes most of the times strike in developing countries, which is one reason why disaster management is a major challenge. The issue of blackout can happen - and as we now know, already happened, - in Austria. Luckily, most of the Austrian people even did not notice the blackout a few years ago in one of the locations of the Vienna Red Cross. Due to good wind circumstances, a disaster could be prevented, and important learnings were made. Nevertheless, attention should be paid on this theme and future research could help for a better understanding and more sensitivity.

7. References

Abounacer, R., Rekik, M. & Renaud, J., 2014. An exact solution approach for multi-objective location-transportation problem for disaster response. *Computers & Operations Research*, Issue 41, pp. 83-93.

Alba, E. & Dorronsoro, B., 2008. Cellular Genetic Algorithms. *Operations Research/ Computer Science Interfaces*.

Bäck, T., 1996. *Evolutionary Algorithms in Theory and Practice. Evolution Strategies, Evolutionary Programming, Genetic Algorithms.* Oxford, New York: Oxford University Press.

Barzinpour, F. & Esmaeili, V., 2014. A multi-objective relief chain location distribution model for urban disaster management. *Int. J. Adv Manuf Technol*, Issue 70, pp. 1291-1302.

Bozorgi-Amiri, A. & Asvadi, S., 2015. A prioritization model for locating relief logistic centers using analytic hierarchy process with interval comparison matrix. *Knowledge-Based Systems*, Issue 86, pp. 173-181.

Bozorgi-Amiri, A., Jabalameli, M. & Mirzapour Al-e-Hashem, S., 2013. A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty. *OR Spectrum*, Issue 35, pp. 905-933.

Caramia, M. & Dell'Olmo, P., 2008. *Multi-objective management in freight logistics: Increasing capacity, service level and safety with optimization algorithms.* 1 Hrsg. London: Springer Verlag.

Chang, F., Wu, J., Lee, C. & Shen, H., 2014. Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling. *Expert Systems with Applications*, Issue 41, pp. 2947-2956.

de la Torre, L. E., Dolinskaya, I. S. & Smilowitz, K. R., 2012. Disaster relief routing: Integrating research and practice. *Socio-economic planning sciences*, Issue 46(1), pp. 88-97.

Deb, K. & Jain, J., 2014. An Evolutionary Many-Objective Optimization Algorithm Using Reference-Point-Based Nondominated Sorting Approach, Part I: Solving Problems With Box Constraints. *IEEE Transactions on Evolutionary Computation*, 08, Issue 18(4), pp. 577-601.

Deb, K., Pratap, A., Agarwal, S. & Meyarivan, T., 2002. A fast and elitist multiobjective genetic algorithm: NSGA-II. *IEEE Transactions on Evolutionary Computation*, Issue 6 (2), pp. 182-197.

EM-DAT, 2017. *The International Disaster Database. Centre for Research on the Epidemiology of Disasters - CRED.* [Online]
Available at: http://emdat.be/advanced_search/index.html
[Accessed 9 04 2017].

Esmaeili, V. & Barzinpour, F., 2014. Integrated decision making model for urban disaster management: A multi-objective genetic algorithm approach. *Internationak Journal of Industrial Engineering Computations*, pp. 55-70.

Golden, B., Kovacs, A. & Wasil, E., 2014. Vehicle Routing Application in Disaster Relief. In: R. Toth & D. Vigo, eds. *Vehicle Routing: Problems, Methods, and Applications (Vol.18).* s.l.:SIAM, pp. 409-436.

Gutjahr, W. J. & Nolz, P. C., 2016. Multicriteria optimization in humanitarian aid. *European Journal of Operational Research*, pp. 351-366.

Hu, Z. & Sheu, J., 2013. Post-disaster debris reverse logistics management under psychological cost minimization. *Transportation Research Part B*, Issue 55, pp. 118-141.

Ing. Alexander Gratz, B., 2016. *Interview: Wiener Rotes Kreuz* [Interview] 2016.

Ing. Mag. Klaus T. Jäger, O., 2016. *Interview: Österreichisches Bundesheer* [Interview] (18 08 2016).

Jozefowiez, N., Semet, F. & Talbi, E., 2007. Multi-objective vehicle routing problems. *European Journal of Operational Research*, Issue 189, pp. 293-309.

Kovács, G. & Spens, K., 2007. Humanitarian logistics in disaster relief operations. *Internaional Journal of Physical Distribution & Logistics Management*, Issue 37(2), pp. 99-114.

Liberatore, F. et al., 2014. A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics. *Computers & Operations Research*, Issue 42, pp. 3-13.

ORF, 2015. *Bewohner kehren in Ort nahe Fukushima zurück.* [Online]
Available at: http://orf.at/stories/2296982/
[Zugriff am 28 07 2016].

ORF, N., 2013. *8,06 Meter: Pegelrekord in Korneuburg.* [Online]
Available at: http://noe.orf.at/news/stories/2587403/
[Zugriff am 04 06 2017].

Ortuno, M., Tirado, G. & Vitoriano, B., 2011. A lexicographical goal programming based desicion support system for logistics of Humanitarian Aid. *Top*, Issue 19, pp. 464-479.

Parlamentskorrespondenz, 2016. *Republik Österreich - Parlament.* [Online]
Available at: https://www.parlament.gv.at/PAKT/PR/JAHR_2016/PK0773/index.shtml
[Zugriff am 07 01 2017].

Podium discussion at the Austrian Parliament, 29.06.2016. *Humanitarian Aid – too important to fail.* Österreichisches Parlament, Wien: s.n.

Rath, S. & Gutjahr, W., 2014. A math-heuristic for the warehouse location-routing problem in disaster relief. *Computers & Operations Research*, Issue 42, pp. 25-39.

Romero, C., Tamiz, M. & Jones, D., 1998. Goal programming, compromise programming and reference point method formulations: linkages and utility interpretations. *The Journal of the Operational Research Society*, 09, Issue 49(9), pp. 986-991.

Scimago Lab, 2017. *Scimago Journal & Country Rank.* [Online]
Available at: https://www.scimagojr.com/journalrank.php?order=sjr&ord=desc
[Accessed 18 08 2018].

Sheu, J. & Pan, C., 2014. A method for designing cenzralized emergency supply network to respond to large-scale natural disasters. *Transportation Research Part B*, Issue 67, pp. 284-305.

Srinivas, N. & Deb, K., 1995. Multiobjective Optimization Using Nondominated Sorting in Genetic Algorithms. *Evolutionary Computation*, Issue 2 (3), pp. 221-248.

Stephenson, R., 1993. *Logistics. UNDP Disaster Management Training Programme.* [Online]
Available at: http://www.pacificdisaster.net/pdn2008/
[Accessed 11 09 2015].

Thomas, A. & Kopczak, L., 2005. *From logistics to supply chain management. The path forward in the humanitarian sector.* [Online]
Available at: http://fritzinstitute.org/PDFs/WhitePaper/FromLogisticsto.pdf
[Accessed 11 09 2015].

Tricoire, F., Graf, A. & Gutjahr, W., 2012. The bi-objective stochastic covering tour problem. *Computers & Operations Research*, Issue 39, pp. 1582-1592.

Tzeng, G., Cheng, H. & Huang, T., 2007. Multi-objective optimal planning for designing relief delivery systems. *Tansportation Research Part E*, Issue 43, pp. 673-686.

Vitoriano, B., Ortuno, M., Tirado, G. & Montero, J., 2011. A multi-criteria optimization model for humanitarian aid distribution. *Journal of Global Optimization*, Issue 51, pp. 189-208.

Wang, H., Du, L. & Ma, S., 2014. Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake. *Transportation Research Part E*, Issue 69, pp. 160-179.

W-KKG, 2017. *Wiener Katastrophenhilfe- und Krisenmanagementgesetz.* [Online]
Available at:
https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=LrW&Gesetzesnummer=20000075
[Accessed 01 05 2017].

World Nuclear Association, 2016. *Fukushima Accident.* [Online]
Available at: http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/
[Accessed 28 07 2016].

8. Appendix A

Guideline for interviews

1) Wie läuft die Katastrophenlogistik allgemein ab?
   a) allgemeine Planung und Ablauf
   b) was wird geplant, was nicht und warum?
   c) gibt es Notfallpläne?
   d) werden diese tatsächlich eingehalten?
2) Läuft die Planung softwaregestützt ab? Wenn ja: was für eine Software wird eingesetzt?
3) Setzen Sie Zieloptimierung ein? Wenn ja: wie und zu welchem Zeitpunkt?
4) Welche Ziele werden verfolgt?
   a) In der Theorie behandeln die meisten Artikel die Optimierung der Deckung/Versorgung der Opfer und der Reaktionszeit. Die meisten berücksichtigen zwar Kosten in Form von Errichtungskosten für Lager oder Routingkosten etc., schreiben aber, dass Kosten in den Anfangsphasen bzw. in der Phase direkt nachdem eine Katastrophe passiert ist, eine eher unwesentliche Rolle spielen. Wie werden Kosten in der Praxis berücksichtigt und an welcher "Stelle" stehen diese dabei?
   b) Welche Zielfunktionen werden tatsächlich eingesetzt?
   c) Wer entscheidet, welche Faktoren bzw. Ziele berücksichtigt werden?
   d) In welcher Form werden Unsicherheiten berücksichtigt (Anzahl Opfer)
   e) Gerechtigkeit, Notlage → wird das berücksichtigt? Wird darauf geschaut, dass die Menschen, die "leichter" zu retten sind zuerst gerettet werden oder werden in jedes Gebiet gleich viele Helfer geschickt?
5) Welche Schritte werden im Vorfeld unternommen, um einen idealen Ablauf anzustreben? Wird in Österreich in Frühwarnsysteme für extreme Wetterereignisse investiert?
6) Welche Probleme gibt es in den verschiedenen Phasen des Katastrophenmanagements?
   a) Was sind die "offenen Baustellen"?
   b) Wo muss man ansetzen um vorhandene Probleme zu beseitigen?
   c) Wird aktuell daran gearbeitet Probleme zu beseitigen?
7) Wie viele Einsätze gibt es durchschnittlich pro Jahr? Nehmen sie tendenziell zu?
   a) Auslandseinsätze

b) Inlandseinsätze
    i) Überblick über die wichtigsten Inlandseinsätze → siehe Ausdruck. Wie viele sind es tatsächlich?
    ii) Heer wird ständig informiert und auf mögliche Katastrophen vorbereitet. Wenn sich Katastrophe anbahnt, bereiten sich Soldaten in Kasernen vor und warten auf Ausrückungsbefehl von Bund, Ländern oder Gemeinden – korrekt? Wie lange wartet man auf so einen Ausrückungsbefehl?
    iii) Landeswarnzentralen tragen dann in ihrer Region Verantwortung und koordinieren Einsatz – da schwerer Regen vor allem ländliche Regionen betrifft: Wiener werden dann z.B. nach Kärnten geschickt, je nachdem wie viele Kräfte gebraucht werden? Freiwillige dürfen sich melden? – wie funktioniert das, i.e. wie erfahren diese von einer Katastrophe? Erst durch Medien?

8) Bei internationalen Einsätzen
    a) Wird mit internationalen Hilfsorganisationen zusammengearbeitet
        i) wie gestaltet sich diese Zusammenarbeit?
        ii) ist das ÖBH anerkannt?
        iii) welche Rolle spielt Politik?
    b) Wer erfährt zuerst, wenn was passiert ist?
    c) Woher kommen die nötigen Informationen?
    d) Sind diese ausreichend?

9) Unterschiede Auslandseinsätze und Einsätze innerhalb Österreichs: Welche Unterschiede bestehen bei Einsätzen innerhalb Österreichs? Gibt es Parallelen?

10) Bei der Veranstaltung "Humanitarian Aid – too important to fail" Ende Juni im Parlament hat der Generalsekretär für internationale Zusammenarbeit der Caritas Christoph Schweifer die dramatische Situation in Äthiopien durch die anhaltende Dürre geschildert und betont, dass auch die Caritas dazu beiträgt, dass mehr Menschen besser für Krisenzeiten gerüstet sind und um die Armut langfristig zu überwinden. Dazu sei auch wichtig, die Bedeutung der lokalen Partner wahrzunehmen und auch lokale NGOs zu stärken, anstelle Hilfe von außen aufzuzwingen. Funktioniert in Auslandseinsätzen die Zusammenarbeit mit lokalen Organisationen? Welche Schwierigkeiten treten hierbei insbesondere auf?

11) Laut Peter Launsky-Tieffenthal, Leiter der Sektion für Entwicklungszusammenarbeit im Außenministerium, wird Österreich ab 2017

Beiträge von 160 Mio. € an die Internationale Entwicklungsagentur der Weltbank beisteuern, insgesamt sei die Unterstützung Österreichs für humanitäre Hilfe so hoch wie schon lange nicht mehr.
Unterstützt das ÖBH im Ausland abgesehen von der Bereitstellung von Helfern in irgendeiner Form (z.B. Bereitstellung von Frühwarnsystemen)?

9. Appendix B

Interview mit Ing. Mag. Klaus T. Jäger, ObstdG, Österreichisches Bundesheer am 18. August 2016 um 14 Uhr im Café Landtmann, Universitätsring 4, 1010 Wien; Dauer des Interviews: 55 Minuten und 21 Sekunden.

Wie läuft in der Katastrophenlogistik die allgemeine Planung beim Österreichischen Bundesheer allgemein ab? Was passiert, wenn eine Meldung eingeht, dass es einen Vorfall gibt? Von wem kommt diese Meldung und im Speziellen interessiert mich die Zieloptimierung. Arbeiten Sie hier mit speziellen Programmen, auf welche Faktoren wird Wert gelegt? Gibt es, wie in der Theorie vorgegeben, Modelle, die angewendet werden? Das Österreichischen Bundesheer hat ja sowohl Inlands- als auch Auslandseinsätze. Wofür sind Sie konkret verantwortlich?

Ich bin für die Logistik im In- und Ausland verantwortlich und auch für Unterstützungsleistungen im Zuge der Migrationslage in Österreich.

Bei meinem Thema geht es nur um Katastrophen und nicht um die Flüchtlings- oder Migrationslage in Österreich.

Für Katastrophen haben wir ein eigenes Kommando. Da gibt es AFDRU-Einheiten (Anm. der Verfasserin: AFDRU = Austrian Forces Disaster Relief Unit). Wenn es eine Katastrophe gibt, wird prinzipiell ein Führungsstab hochgefahren, der die Auswirkungen mit-plottet. Eine Auswirkung könnte sein, dass es direkte, unmittelbare Auswirkungen auf Österreich hat oder aber indirekte Auswirkungen auf Österreich hat, sodass wir eventuell helfen könnten. Dann gibt es auf internationaler Ebene ein Gremium, wo man einfach einen Bedarf einmeldet. Der Bedarf könnte dann durch zig verschiedene Nationen und Organisationen gedeckt werden und der Bedarfsträger, egal jetzt ob Hochwasser, Tsunami oder Brand, sagt dann, sie wollen die Österreicher in der Trinkwasseraufbereitung, die Deutschen mit dem Feldspital und die Amerikaner mit der Versorgung der Betriebsmittel, Medikamente, Verbandsmaterial. Das ist also komplett unterschiedlich.

Das bedeutet, es gibt dann von "oben" den Auftrag, wer wo hilft?

Genau.

Wenn es heißt, Österreich ist verantwortlich für die Trinkwasseraufbereitung…

… gibt es intern Pakete, das beginnt bei der Alarmierung, dann gibt es eine ganz kurze Formierung, weil die Einsatzvorbereitung abgeschlossen ist. Man ist also durchgeimpft, man hat einen weltweiten Impfschutz. Man hat die Ausrüstung zuhause, man hat günstiger Weise einen Container verpackt, nicht nur mit der persönlichen Ausrüstung, sondern mit der Ausrüstung, die man braucht. Das sind eben Trinkwasseraufbereitungsanlagen, das sind für die Eigenversorgung Zelte, Verpflegung, Verbindungsmittel wie Funkgeräte, Ausrüstungsätze für erweiterte Selbst- und Kammeradehilfe, das können auch Rettungs- und Bergelemente sein. Das ist also fertig gepackt, wird zusammengebracht und dann entweder mit dem Flugzeug, das wir auch wieder selber haben, ins Zielgebiet gebracht, mit einem angemieteten Flugzeug, auf der Straße oder auf der Schiene, je nachdem wie weit der Einsatzort entfernt ist und was am schnellsten geht. Das ist also sehr wohl alles vorbereitet.

Ist es immer so, dass Österreich für die Trinkwasseraufbereitung zuständig ist?

Nein, das kann unterschiedlich sein.
Auch bei Inlandseinsätzen. In Stanz hatten wir zum Beispiel eine Umweltkatastrophe mit Murenabgängen und auch dort wird dieser Einsatz geführt. Die wissen, jetzt brauchen sie Pioniere und vom Kommando Logistik einen Notarzt, Rettungssanitäter und die Betriebsmittelversorgung und einen Tank. Sie hatten dann ein Norm-Notarztteam und alle 48 Stunden einen Tankwagen zu betanken.

Das heißt, es ist nicht so, dass man sagen kann, das Bundesheer hat eine eigene Zieloptimierung im Fall von Katastrophen und entscheidet, wie beispielsweise Kosten berücksichtigt werden. Also Sie sind nicht derjenige, der entscheidet, was "wichtiger" ist, ob das oberste Ziel ist, so viele Menschen wie möglich zu retten oder inwiefern die Kosten berücksichtigt werden?

Menschenleben haben immer Priorität, das ist ganz klar. Die Kostenkomponente hat nicht die Priorität, die sie scheinbar zu haben scheint.

In der Theorie ist es so, dass Kosten sehr wohl meist berücksichtigt werden, jedoch nicht als Primärziel, sondern immer erst nachher, wenn man in einem Katastrophenfall, beispielsweise nach einem Tsunami, dann die Lager aufbauen muss. Sprich, die Kosten, die benötigt werden, um das Lager aufzubauen werden sehr wohl berücksichtigt und in *der Phase ein oder zwei Jahre nach der Katastrophe, wenn es dann um den Wiederaufbau geht, sind die Kosten schon ein großer Faktor, weil es am Geld oft fehlt.*

Das ist für uns komplett irrelevant, weil wir das Primat der Politik haben. Der Hauptausschuss vom Nationalrat kann entscheiden, ob wir den Einsatz machen oder nicht. Dann ist es Aufgabe des Heeres, das durchzuführen. Es gibt zwei Ausnahmen: das eine ist, wenn es jetzt eine Unterstützungsleistung gibt, zum Beispiel für das Innenministerium, dann führen wir beispielsweise die Transporte durch und das muss finanziert werden. Nicht vom Heer, sondern entweder vom Innenministerium oder einer Sonderfinanzierung vom Finanzministerium. Wenn es jetzt regionale Katastrophen gibt, zum Beispiel ein Bohrgerät rutscht bei einer Bohrung den Hang hinunter, es tritt Öl aus und es könnte zu einer Grundwasserverschmutzung kommen, ist es Sache der Landesebene zu sagen, es ist ein Katastrophenalarm, es können keine zivilen Ressourcen mehr herangeholt werden, weil im Prinzip wären wir eine Konkurrenz zu den zivilen Leistungsträgern, das dürfen wir nicht sein. Das heißt die Landeswarnzentrale sagt dann, es ist ein Alarm und jetzt darf das Heer eingesetzt werden. Dann sind aber keine Kosten zu verrechnen, weil es Kernaufgabe des Heeres ist. Die Kosten werden immer nur verrechnet bei Zusatzleistungen.

Zum Vergleich Inlands- und Auslandseinsätze: Sie haben ja gesagt, bei Auslandseinsätzen bekommt das Land Österreich immer nur eine Kernaufgabe. Ist das bei Inlandseinsätzen auch so?

Definition Kernaufgabe ist jetzt welche?

Eine Kernaufgabe wäre die Trinkwasseraufbereitung. Dann kümmern Sie sich im Ausland ausschließlich darum.

Nein. Beim Tsunami, den es vor 11 Jahren gegeben hat, ging es auch um den Wiederaufbau und um Erste Hilfe, wobei die Erste Hilfe natürlich nicht mehr für die Verletzten vom Tsunami war, sondern in Folge der Opfer. Sprich, das Rote Kreuz ist dort… schlechtes Beispiel, die können sich selbst helfen. Irgendeine andere Organisation ist dort und die Einheimischen sind dort und kommen mit einem kranken Kind oder einer schwangeren Frau, etc. Da sind dann Sanitätselemente dabei und zwar nicht nur für die Eigenversorgung des Heeres oder für andere Soldaten, die im Verbund dort sind, sondern da werden im Prinzip alle versorgt. Auch, wenn die Aufgabe primär die Trinkwasseraufbereitung sein soll. Also es wird immer das gesamte Spektrum angeboten.

Funktioniert die Zusammenarbeit mit anderen Organisationen grundsätzlich?

Ja, sehr gut.

Also dahingehend gibt es keine Probleme mit den internationalen Hilfsorganisationen?

Nein, da gibt es definitiv keine Probleme, weil es geringe Schnittstellen gibt. In Bosnien zum Beispiel waren wir nach dem Krieg. Wenn da jetzt eine internationale Hilfsorganisation aus Österreich kommt, "Saatgut für den Frieden" zum Beispiel, oder Caritas, natürlich können die im Notfall zu uns kommen, bekommen Verpflegung, Unterkunft, Erste Hilfe. Verpflegung müsste aber verrechnet werden, Unterkunft auch. Aber ansonsten sind die Aufgabenbereiche unterschiedlich. Wir haben zum Beispiel den Transport des Saatgutes hinunter, Transport für Material für den Dachstuhlbau, wir hatten Awareness-Training, und die zivilen Organisationen hatten die Finanzierung von einer Schule. Da gab es eine komplette Trennung.

Wenn es jetzt so ist, dass Sie den Transport zu organisieren haben; wer gibt vor, was wohin geliefert wird?

Immer der, der den Transportauftrag gibt. Wenn jetzt eine Organisation in Österreich Kleidung gesammelt hat, dann sagt sie diese Kleidung wird aufgeteilt: 50 Prozent bekommen die Bosnier, 30 Prozent die Kroaten und 20 Prozent die Serben in Bosnien, dann führen wir es dort hin, wo die zivilen Organisationen das hin haben wollen. Da ist unsere Kompetenz nur der Transport. Wenn Sie jetzt ein Paket bei Amazon bestellen und Sie wünschen, den Herrn X als Empfänger, transportieren sie das. Das ist bei uns komplett gleich.

Wenn man jetzt einen Auslandseinsatz hat und man muss in dem Land etwas von A nach B transportieren, müssen Sie ja damit rechnen, dass es beispielsweise Brücken nicht mehr gibt, weil sie eingestürzt sind oder Straßen nicht befahrbar sind. Wird dann spontan eine Ausweichroute gefunden oder werden in so einem Fall vorher schon Maßnahmen gesetzt?

Es gibt vorher eine Erkundung, die eine Woche, bis ein Monat oder am Tag davor sein könnte. Da gibt es alle Erkundungsmöglichkeiten, die wir haben. Angefangen von Luft- und Satellitenfotos bis hin zur Straße. Wenn man jetzt umfangreichere Transporte hat, schwere Systeme, wir haben zum Beispiel ganze Fabriken runtergeführt, dann wird alles mit einem Kleinfahrzeug abgefahren, weil Hakenlastsysteme einfach Probleme hätten bei den Brücken. Dann gibt es die Variante, dass wir den Transportweg optimieren, sprich eine andere Route wählen. Oder wir lassen die Brücke verstärken, da sind oft Pionierkräfte dabei, die sich die Brücke anschauen und sagen, hier können 18 Tonnen drüberfahren oder nicht. Oder es muss auf den Gegenverkehr verzichtet werden und es braucht eine Militärstreife, die den Gegenverkehr abblockt. Wenn die Brücke verstärkt gehört, kommen Pioniere hin und würden die Brücke so verstärken, dass wir mit allen Elementen drüberfahren können. Also das ist perfektioniert. Da gibt es auch Lagekarten, welche Brücke welches Gewicht aushält, entweder in beide Richtungen gleichzeitig oder in einem Einbahnsystem.

Diese Informationen gibt es ja alle schon im Vorhinein.

Ja, außer die Brücke ist zerstört worden, so wie jetzt eben in Ungarn an der Grenze zu Serbien, dort brauchen wir Baupioniere, die die Straßen bauen und da wird mit den Pionieren auch ein Transportelement mitgeschickt, damit wir sehen, wo kann man untergebracht werden, wo können die Fahrzeuge hingebracht werden.

Es ist interessant, wie Theorie und Praxis da auseinandergehen.

Ja, also Kosten sind definitiv irrelevant. Wenn wir von der Politik einen Auftrag bekommen, ist der umzusetzen. Die Details der Umsetzung sind dann komplett frei, wenn wir natürlich die berechtigten Vorgaben einhalten. Ausschreibeverfahren gibt es genauso. Wenn wir in einem längeren Einsatz wären, brauchen wir beginnend bei Sandsäcken, über Mobiltelefone für den Einsatzraum eine Suche von 3 bis 5 Firmen und der beste Anbieter wird dann genommen.

Dafür hat man Zeit?

Bei einem längeren Einsatz, ja.

Wenn sofort Maßnahmen gesetzt werden müssen, geht das natürlich nicht.

Nein.

In Österreich gibt es auch Frühwarnsysteme?

Ja, Alarmierungssysteme gibt es. Das Wetter wird laufend mitgeplottet. Bei jedem Einsatz gibt es mindestens ein bis zweimal in der Woche ein Wetterbriefing. Das fängt an bei der Passierbarkeit von Straßen, wenn wir jetzt einen Einsatz in Mali hätten und dort ist Regenzeit, dauert der Transport die zehnfache Zeit. Das endet bei den Flugdaten, ob wir jetzt einen Nothubschrauber starten lassen können oder es zu einer Vereisung kommt. Das ist immer ein Kriterium, das man vorher schon braucht, bevor man irgendeinen Transport durchführt.

Sind diese Informationen, die man im Vorhinein braucht, ausreichend? Oder müssen im Nachhinein unbedingt erforderliche Informationen eingeholt werden?

Alle Informationen werden immer upgedatet. Wenn jetzt zum Beispiel ein Erdbeben in Haiti ist und wir gehen nach Haiti, machen wir jetzt ein Lagebild, was für die Sanitäter die medizinischen Herausforderungen dort sein werden. Giftschlangen, Stechmücken, die das Zika-Virus verbreiten, also das machen wir sehr wohl. Bis hin zu der Entscheidung, ja wir fliegen mit dem Flugzeug hin oder wir mieten ein Flugzeug an, kann das dort überhaupt noch landen? Also das wird sehr wohl immer upgedatet.

Das betrifft ja auch den Selbstschutz, weil man ja seine eigenen Leute in ein Gefahrengebiet schickt. Da muss man schon Sicherheiten haben.

Ja, impfen und die entsprechenden Medikamente mitnehmen. Wenn ich jetzt im Wald einen Einsatz habe und weiß, dort gibt es keine Giftschlangen, dann brauche ich keine Anti-Schlangen-Seren mitnehmen. Wenn ich in Afrika bin, brauche ich vermutlich kein Grippemittel, obwohl bei den Klimaanlagen wahrscheinlich trotzdem.

In der Theorie gibt es ja die verschiedenen Phasen im Katastrophenmanagement. Werden in der Praxis die Kosten in der Phase des Wiederaufbaus auch nicht berücksichtigt?

Beim Wiederaufbau noch am ehesten, wobei der Wiederaufbau nicht unsere Aufgabe ist. Es gibt eine Ausnahme, beim CIMIC (Anmerkung der Verfasserin: Civil-Military Co-operation), also der zivilen-militärischen Zusammenarbeit. Wenn also entschieden wird, wir bauen eine Schule wieder auf oder wir graben einen Brunnen neu oder wir bauen für die Schüler einen Tennisplatz, dann machen wir das sehr wohl. Aber es muss immer einen CIMIC-Hintergrund haben.

Ich habe mir im Vorfeld die Inlands- und Auslandseinsätze angesehen. Die Assistenzeinsätze im Inland gehen zwar nur bis 2011. Können Sie mir in etwa sagen, wie es im Jahr 2015 aussieht?

Da habe ich den Zugang nur in der Kaserne, das kann ich Ihnen zukommen lassen.

Werden es tendenziell mehr Einsätze?

Das wäre jetzt ein Bauchgefühl, das kann ich momentan nicht beantworten. Da habe ich jetzt keine validen Zahlen.

Ist es korrekt, dass das Bundesheer im Ausland anerkannt ist?

Ja.

Da haben Sie schon eine hohe Reputation und einen hohen Stellenwert?

Ja.

Die Autoren der Artikel betonen auch immer wieder, dass man den lokalen Organisationen die ausländische Hilfe nicht aufzwängen soll, weil es ja die Wirtschaft vom eigenen Land ankurbelt, wenn die eigenen Organisationen mehr machen können. Wie ist die Zusammenarbeit mit den lokalen Organisationen? Herrscht da Konkurrenz?

Der Staat an sich sieht die Vorteile. Erstens brauchen sie ja die Streitkräfte und zweitens bringen wir auch Kapital ins Land. Das Essen wird dort eingekauft, man geht am Abend auf einen Kaffee, man redet mit den Einheimischen. Konkurrenz mit den anderen Katastrophenhelfern … das ist eine interessante Frage. Kaum. Weil wir ein anderes Spektrum abdecken. Also es gibt kaum zivile Firmen, die in ein Gebiet hineingehen, wo Minen sind. Es gibt natürlich Firmen, die sich auf Minen spezialisiert haben, dann machen sie das sehr gerne. Das wird dann aber auch vom Heer vorkoordiniert. Es gibt Minenlagenkarten, es gibt diverse Firmen, die finanzieren die Räumung von einem Stadtpark zum Beispiel. Da gibt es nur eine Koordination, wo jeder zum Ziel hat, dass die Minen weniger werden. Wenn Sie eine Entscheidungsfrage stellen: im persönlichen Bereich gibt es vielleicht Neid, das kann schon sein aber nicht strukturiert.

Das heißt, sie freuen sich, dass sie Hilfe bekommen?

Jein. Es ist schwierig. Wenn wir jetzt zivile Organisationen hernehmen, zum Beispiel UNDP, die in Bosnien aktiv sind. Solange Alpha dort ist und UNDP dort ist, ist es genialst. Warum? Es sind ja zig Arbeitsplätze. Wenn jetzt tiefster Friede wäre, dann hätte der Mitarbeiter oder die Mitarbeiterin von UNDP in Sarajewo, der jedes Monat oder jedes Wochenende um 100 Euro nach Wien zurückfliegen könnte, keinen Job mehr. Und dann kann er sich bewerben für einen Auftrag bei UNDP in Afrika. Als ein Bewerber, eine Bewerberin von 70 anderen. Das wäre jetzt vielleicht eine Themenverfehlung, ist aber auch Realität. Man hat als einzelner Mitarbeiter bei Hilfsorganisationen in Sarajewo überhaupt keinen Stress, weil das alles sehr lang dauert und das ja ein Werkvertragsbasisjob ist, der immer verlängert wird, solange es einen Auftrag dort gibt. Wenn der weg ist, muss ich mich vielleicht Richtung Krim oder Mali bewerben. Und es ist menschlich zutiefst verständlich, dass ich lieber in Sarajewo bin, dort Filmfestspiele habe, ein Theater habe, Österreicher habe und in einer Stunde in Schwechat bin und nicht in Krim bin, wo noch immer geschossen wird oder in Mali bin, wo es andere Herausforderungen gibt. Aber konkret Ihre Frage: Reibung und Neid eher nicht, nein. Im Inland zum Teil schon, aber jetzt wären wir wieder bei der Migrationslage. Auf Arbeitsebene nicht, auf Entscheidungsträgerebene zum Teil, zum Beispiel zwischen MA70 und Rotes Kreuz. Die MA70 ist in Wien zuständig für die Katastrophenhilfe und koordiniert die Berufsrettung, das Rote Kreuz, das Schwarze Kreuz, den Arbeitersamariterbund, alles in Wien. Das Rote Kreuz koordiniert ganz Österreich, außer Wien. Das ist schwer nachvollziehbar, aber interessant.

Darf ich Ihren Zettel mit den Fragen sehen? (Sehen Sie dazu Appendix A – Guideline for interviews)

Selbstverständlich.

(ad 1c) Also die Notfallpläne werden eingehalten, ja. Man passt sie nur an. Wenn man jetzt sieht, man hat einen gemeinsamen Einsatz mit der MA70, dem Roten Kreuz oder dem Innenministerium. Da gibt es eine eigene Plattform, wo man parallel Strukturen weiterhin nutzt. Weil unsere Alarmierung ist unsere Alarmierung, die vom Roten Kreuz ist die vom Roten Kreuz.

Wer stellt diese Notfallpläne auf?

Die jeweilige Organisation für sich.

(ad 4a) Zu der Optimierung der Versorgung der Opfer. Bei den Opfern ist es insofern wichtig, dass es die Golden Hours, oder Six Hours gibt, bei einem Erdbeben zum Beispiel oder bei einem Einsturz von einem Gebäude. Deswegen gibt es einen so hohen Readiness-Grad, weil das AFDRU-Element einfach mit Rettungs- und Bergeteams oder mit den Suchhunden relativ rasch dort sind.

Die Kosten in der Praxis haben definitiv keine Priorität. Entscheidend ist immer nur die Auftragserfüllung in der vorgegebenen Zeit.

Das heißt es geht um die Reaktionszeit?

Ja.

(ad 4a und 4e) Es gibt sehr wohl eine Triage. Wenn Kapazitäten und Ressourcen eingeschränkt sind, dann rettet man denjenigen/ diejenige mit der größten Überlebenswahrscheinlichkeit zuerst. Wenn jetzt hier etwas wäre und wir beide hätten einen offenen Darmaustritt und die am Nebentisch hätten eine Schnittverletzung am Oberarm und bluten, würden die zuerst gerettet werden und wir zwei hätten Pech. Weil wir zwei würden wahrscheinlich 2 Ärzte und 3 Notfallsanitäter binden für 6 Stunden und von den anderen mit Splitterverletzungen würden 20 gerettet werden können. Also die Triage gibt es sehr wohl. Wenn jetzt jemand eine leichte Verletzung hat und herumschreit, weil er noch nie Blut gesehen hat: der hat überhaupt Pech. Den lasst man halt schreien, weil das ist nichts Lebensbedrohliches. Das ist aber eine reine medizinische Beurteilung und wurde nicht wirtschaftlich errechnet.

Wenn nach einem Tsunami einige Gebiete schwerer zugänglich sind als andere, in welche fährt man zuerst? Oder schickt man gleichzeitig Helfer hin?

Die Beurteilungsgrundlage ist wo ist die Gefährdung am geringsten? Wenn jetzt eine Hangrutschung in einem Minengebiet ist und zeitgleich gibt es eine Hangrutschung wo die Bevölkerung auf uns wartet, würden wir Priorität dort haben, wo die Bevölkerung auf uns wartet und keine Minen sind. Diese Komponente kommt auch noch hinzu. Und dieses Frühwarnsystem Wetterverhältnisse gibt es natürlich auch in der praktischen

Umsetzung. Wenn wir wissen, es gibt im Winter Lawinen, werden im Winter Lawineneinsatzzüge vorbereitet, die genauso alles schon gepackt haben, angefangen von der kompletten Lawinenausrüstung, Ski, Verschütteten-Suchgeräte bis hin zur Lawinensonde. Die sind dann sofort im Einsatz. So geht man schon auf das Wetter ein.

Ja darauf bin ich im Zuge meiner Recherche gestoßen, dass man die Wetterlage immer upgedatet hat und kontrolliert und sollte sich etwas anbahnen, wird man im Vorfeld informiert, damit alles vorbereitet werden kann.

Richtig.

(ad 6) Offene Baustellen sind eher die Transportkapazität, was strategischen Lufttransport betrifft. Wir könnten jetzt zwar mit drei C130-Systemen nach Afrika fliegen, aber das wäre schon alles. Wir könnten natürlich einen strategischen Lufttransport anmieten, nur bei einer Katastrophe will jede Nation jetzt den Lufttransport, weil jeder helfen will. Also Transportkapazität ist sicher eine Herausforderung.

Probleme sind auch die eingeschränkten Ressourcen in jedem Bereich. Da muss man einfach Schwergewichte bilden.

Eingeschränkte Ressourcen auch personell?

Naja die Vorgabe ist 1.100 pro Jahr im Schnitt im Ausland zu haben, die sind auch im Ausland. Natürlich kann man Spitzen auch abdecken. Wir haben immer diese AFDRU-Elemente im Inland, wir haben immer Lufttransportkapazität im Inland, wir haben immer 70 Hakenladesysteme und 29 Großraumbusse für den Transport im Inland. Wir haben immer eine Bevorratung von Medikamenten, Impfstoffe, Verbandsmaterial, also das ist immer da. Das ist eher nicht das Problem.

Frage 7: es gibt einen Vorbefehl. Beispiel mit dem Bohrgerät war real. Da gab es eine interne Kommunikation vom Bezirkshauptmann zum Kasernenkommandant und der hat dann eine Übungsfahrt mit einem Bergepanzer gemacht. Das kann er ja immer machen, weil noch nicht entschieden wurde, ob es eine Katastrophe ist für die Umwelt und dann war der Bergepanzer in der Nähe. Also hier wird vorbereitet. Genauso die Lawineneinsatzzüge: die sind gepackt, die Alarmierung ist trainiert und wenn eine Lawine abgeht, werden die einfach geholt.

Es werden nicht Wiener nach Kärnten geschickt, es geht echt darum, wenn wir jetzt Pioniere brauchen, das sind die Pioniere in Villach, in Salzburg und in Melk, wenn jetzt in Kärnten etwas passiert, kommen natürlich die Villacher Pioniere dran, wenn sie zur Zeit der Katastrophe die Kapazität haben. Wenn jetzt aber die Pioniere in Villach gleichzeitig die Grenze am Brenner und in Nickelsdorf und in Spielfeld ausbauen und wenn die gerade kein Vollkontingent an Rekruten haben, wenn alle in Melk zur Verfügung stehen, dann würde man natürlich die Melker Pioniere sofort nach Kärnten schicken und nicht alles andere liegen und stehen lassen, einrücken und sich formieren. Also wir denken da schon mit.

Die Frage habe ich genommen, weil ein Kollege sich auch für solche Einätze freiwillig gemeldet hat und eben nach Kärnten geschickt worden ist. Er hat mir erzählt hat, dass er auch immer die Ausrüstung gepackt zuhause hat und wenn was passiert, holt er seine Sachen und weiß schon, wo er sich melden muss.

Ja, es können Freiwillige sein beim Heer, die auch zum Beispiel als Beifahrer in einem Großraumbus mitfahren, wenn Flüchtlinge transportiert werden. Kommunikation über Handy mit der Verkehrsleitzentrale, Kontakt aufnehmen mit den Flüchtlingen, damit sie dem Fahrer nicht sagen, dass sie aufs WC müssen oder die Temperatur zu heiß ist. Das ist eine Variante. Dann gibt es natürlich Milizsoldaten oder Reservesoldaten, die, wie Sie es gerade gesagt haben, alles zuhause haben und kommen können. Dann gibt es noch Leute, die bisher mit dem Heer nichts am Hut hatten und auf Basis des §15 ihr eigenes Geld bekommen, wenn zum Beispiel eine diplomierte Gesunden- und Krankenpflegerin mit uns nach Ungarn will. Das ist auch eine Variante, die werden dann von der Firma oder vom Krankenhaus freigestellt, werden von uns finanziert und sind dann mit uns gemeinsam im Einsatzraum.

(ad 8) Politik hat entscheidende Rolle. Ohne Politik, ohne politische Vorgabe machen wir überhaupt nichts.

Wer erfährt zuerst, wenn etwas passiert? Es gibt ein Lagezentrum, das dauernd besetzt ist. Die plotten auch die Medien mit. Die sind international vernetzt und die würden dann ab einer gewissen Ebene den Generalstabchef alarmieren, der wiederum den Bundesminister und der rein theoretisch wiederum die Bundesregierung. Wobei das wiederum von der Katastrophe abhängt. Sehr vieles wird vom Innenministerium koordiniert, was die Kernkompetenz ist, bis hin zu einer „Siebenerlage". Eine

„Siebenerlage“ ist eine Koordinierungsplattform mit dem Innenministerium, Verkehrsministerium, Gesundheitsministerium; es sind je nach Bedarf dabei die ÖBB, Rotes Kreuz, Caritas, MA70 Wien und eben das Bundesheer. Dort wird zwischen zweimal am Tag bis einmal alle vierzehn Tage koordiniert, wie es weitergehen sollte. Das hat immer nur eine Koordinierungskompetenz, keine Entscheidungskompetenz. Also wenn das Innenministerium einen Befehl gibt, hat das Rote Kreuz ein Spital hier zu errichten.

Zu Frage 8d: Wenn Sie die Information bekommen, dass Sie für die Trinkwasseraufbereitung verantwortlich sind: Sind die Informationen, die Sie brauchen, um das zu managen und aufzubauen ausreichend?

Das ist das Wissen, das ich brauche, um Entscheidungen zu treffen. Das ist das Wissen, das ich habe. Ich weiß, welches Personal und welche Funkgeräte ich habe und wie weit es dort hin ist. Und das ist das Wissen, was ich glaube, was ich brauchen würde, um eine Entscheidung zu treffen. Wenn also das Delta zu groß ist, dann kann ich einfach eine Aufklärung ansetzen. Von Internetresearch bis hin zum Erkundungsteam, man wird nie alles wissen, was man brauchen würde. Man trifft Entscheidungen aufgrund von Annahmen.

Aber mit den Ihnen zur Verfügung stehenden Informationen können Sie den Einsatz immer absolvieren?

Ja.

(ad 9) Unterschied Aus- und Inland ist klar. Allein der rechtliche Ablauf ist ein ganz anderer.

Natürlich können wir Trinkwasser aufbereiten, aber wenn man dann rechnet, was ein Liter Trinkwasser kostet, der Flug dort hin, das Gerät, die Personalkosten, etc.; um dieses Geld könnte man ganz viel Mineralwasser kaufen. Wenn jetzt Sie in Äthiopien sagen, Sie haben 50.000 Euro pro Woche, bringt das Mineralwasser her. Gibt es sofort zig Firmen, die das Mineralwasser hinbringen; ohne Hilfsorganisationen, ohne NGOs. Frage 10 haben wir schon besprochen.

Korrekt. Das heißt Sie haben all meine Fragen beantwortet. Vielen herzlichen Dank, dass Sie sich die Zeit für mich genommen haben.

10. Appendix C

Interview mit Ing. Alexander Gratz, BA, Bereichsleiter Katastrophenhilfsdienst vom Österreichischen Roten Kreuz, am 8. September 2016 um 11 Uhr in der Karl-Schäfer-Straße 8, 1210 Wien; Dauer des Interviews: 48 Minuten und 43 Sekunden.

Sie sind Bereichsleiter für Katastrophenhilfe und implementiert auch die -logistik als eine Einheit. Welche Aufgaben fallen unter diesen Bereich?

Ich bin Bereichsleiter im Katastrophenhilfsdienst im Wiener Roten Kreuz und Wien ist eine Sonderheit im Vergleich zu anderen Bundesländern, weil Stadt Wien hat in der Kat-Vorhaltung zwei eigene Magistratsabteilungen, einmal die MA68 Feuerwehr und die MA70 Berufsrettung Wien. Es gibt für die Vorhaltung von Material und Personal keinen Ersatz. Trotzdem halten wir, auch um kompatibel mit den österreichweiten Einheiten der anderen Bundesländer zu sein, die gleichen Einheiten vor. Das heißt in unserem Katastrophenhilfsdienst haben wir eine Bereitschaft Suchhunde, wir haben Wasseraufbereitungstechniker, wir haben eine Spezialeinheit für Unterkunft, Betreuung und Camp, eine Einheit CBRN – chemische, biologische, radioaktive, nukleare Spezialisten vor allem für den Selbstschutz unserer Mitarbeiter, die uns auch berät wie man sich im Fall des Falles verhält, wenn Grippewellen oder Epidemien und Pandemien kommen. Wir haben einen Fernmeldedienst, mit dem wir auch autark im Stromausfall, einer unserer Fokusse ist Blackout, die Kommunikation aufrechterhalten können. Wir haben eine Bereitschaft Logistik, die darauf schaut, dass wir alle notwendigen Dinge haben, die wir brauchen. Eine Bereitschaft Verpflegsdienst, das sind unsere Köche. Eine unserer Kernaufgaben in Wien ist „Unterkunft, Betreuung, Camp“ und da gehört diese Einheit dazu. Wir haben eine Supporteinheit Technik, die unterstützen uns bei Fragen zu Strom und Wärme. Diese Einheiten finanzieren wir über Spenden. Wir bilden die Mitarbeiter und Führungskräfte aus, haben eine eigene Kat-Ausbildung und dieses System gehört an die Rahmenbedingungen angepasst, unterstützt und weiterentwickelt und ein Faktor, wo wir das in der Praxis auch anwenden, sind Ambulanzdienste. Es gibt das Veranstaltungsgesetz, möchte man beispielweise ein Fußballmatch ausrichten oder eine Geburtstagsfeier mit einer gewissen Anzahl an Besuchern, schreibt die MA36V – Veranstaltungsbehörde eine gewisse Anzahl an Notärzten und Sanitätern vor und das bieten wir auch an. Bei kleineren Geschichten wäre all das bisher besprochene egal, aber bei größeren Veranstaltungen wie zum Beispiel dem Vienna City Marathon oder dem zweitägigen Helene Fischer Konzert letztes Jahr wäre das ohne diese Supporteinheiten nicht möglich. Wenn man so eine große Ambulanz wie beim Vienna City Marathon mit über 300 Mitarbeitern plant, gehört natürlich auch eine entsprechende Führungsstruktur mit dazu und da steht ein gewaltiger Logistikplan dahinter, weil da alles auf der grünen Wiese zu 100 Prozent autark – mit Supporteinheiten aus anderen Landesverbänden, hauptsächlich Sanitätern – mit eigenen Materialien aufgebaut wird, also eigene Zelte, eigene Wasserversorgung. Das ist so im Groben die Beschreibung meines Bereiches, ein großer Punkt ist im letzten Jahr noch herausgestochen, das war die Flüchtlingshilfe, was aber im Endeffekt prinzipiell mit all den vorher genannten Einheiten abdeckbar ist. Dort war das Momentum Dauer und die Dimension, diese Punkte waren die Herausforderung bei diesem Thema.

Speziell zur Katastrophenlogistik, wie ist Ihre Planung? Es gibt ja in Österreich Frühwarnsysteme, die laufend Informationen übermitteln. Wenn vorhergesagt wird, dass in zwanzig Stunden ein Ort in Niederösterreich überflutet sein wird, wie gehen Sie dann vor?

Rein von der Logistik her gibt es zwei Ansätze. Prinzipiell: möchte ich die Leistungen zukaufen und halte ich keine Transportmittel vor oder der andere Weg – für den wir uns entschieden haben – habe ich einen Minimumfuhrpark und kann die erste Phase aus eigenen Kräften bewältigen. Darauf haben wir uns festgelegt. Das ist natürlich ein Kostenfaktor, das heißt wir halten einen 26-Tonnen-LKW vor, einen 7-Tonnen-LKW und einige andere Transportfahrzeuge - also Kastenwägen, Pritschenwägen - und somit können wir die Leistungsparameter, die wir angeben und erfüllen können, in der ersten Phase selbst transportieren und anliefern.

Sind diese Fahrzeuge schon beladen?

Nein, diese Fahrzeuge sind noch nicht beladen.

Also muss dann schnell entschieden werden, was benötigt wird. Gibt es an diesem Standort ein Lager?

Ja, es gibt mehrere Lager in Wien und natürlich in Österreich verteilt. Wenn wir jetzt von Wien sprechen, haben wir hier im Haus ein Lager, da lagern wir Aggregate, Zelte und Feldbetten, um hundert Leute autark über einen Zeitraum von ein paar Tagen in dieser Struktur unterzubringen. Das heißt wir können hundert Leute in beheizten Zelten mit Strom unterbringen, worst case wäre im Winter. Das haben wir sofort verfügbar und das ist durch die Transportwege zum LKW innerhalb von dreißig Minuten verladen. Alles befindet sich auf Rollwägen und Paletten und alles mobil verbringbar. Es handelt sich um ganz kurze Wege und das ist elementar hier, das ist auch durch Hilfskräfte verladbar.

Wer hat entschieden, dass genau hundert Leute versorgt werden können?

Das ist nicht die wichtigste Zahl, das war ein Rahmenparameter, auch finanziell – das ist die Größe von Übungen bei uns. Wenn wir zwei Mal im Jahr Ausbildungen machen, sind in etwa hundert Leute unterzubringen und das ist bei uns die Größe.

Das ist aber wirklich ein kleines Tortenstückchen. Prinzipiell arbeiten wir vor allem was Unterkunft/ Betreuung betrifft, logistisch gesehen auf Anhängerbasis, weil das einfach das Billigste ist. Das heißt, wir haben hier keine großen Wartungskosten und ich habe hier mehrere Anhänger schon fertig beladen und die Leute ausgebildet. Ich kann Ihnen da auch gerne Beispiele oder Zahlen geben. Das ist dann skalierbar. Bei diesen hundert Leuten brauche ich einmal einen LKW damit ich wirklich alles dort hab. Dann gibt es natürlich die verschiedenen Taktiken, die wir haben. Einerseits, dass Hilfskräfte diesen Anhänger innerhalb einer vorgegebenen Zeit zum Ort des Geschehens bringen – in den meisten Fällen eine Stunde. Diese liefern das Material an, das ist beschriftet, der Deckel vom Hänger wird aufgemacht, die Fachkräfte kommen hin und arbeiten mit ihrem Material. Anderseits mit minimalem Material, das wäre jetzt zum Beispiel eine Unterbringung in einer festen Unterkunft, da brauche ich den LKW in erster Linie nicht, sondern da fahr ich mit meinen Anhängern hin, da habe ich ein paar Feldbetten für Bedürftige und Heurigengarnituren drinnen, einen Minimalbestand an Lebensmitteln und Getränken, um dort die Leute wirklich eine Stunde nach Alarmierung minimal zu versorgen. Dann wird von hinten nach Taktik die Maschinerie hochgefahren, da wird entschieden, ob die Leute dort schlafen müssen, ob man eventuell externe Toiletten oder Duschen braucht und was sonst noch zu adaptieren ist, um die Leute entsprechend unterzubringen. Hauptsache ist, die Leute nicht auf der Straße stehen zu lassen.

Das bedeutet, es gibt Notfallpläne, die auch größtenteils eingehalten werden?

Genau. Es gibt einen Standardprozess, einen Landeseinsatzplan für Wien, da sind eine Anzahl an Kriterien, die eintreten können in Katastrophen angegeben und je nach Abfragesystem, also je nachdem welcher Großunfall oder welches Szenario eingetreten ist, werden automatisch von unserer Leitstelle, die 24 Stunden besetzt ist, die entsprechenden Rettungskräfte erstalarmiert. Also nicht nur Rettungskräfte, sondern auch die Katastrophenhelfer, die Fachkräfte.

Also Sie werden von der Leitstelle informiert?

Prinzipiell ist es so: Wenn etwas passiert, gibt es einen behördlichen Einsatzleiter und dort wird das Wiener Rote Kreuz nachalarmiert oder überhaupt alarmiert was zu tun und normalerweise geht dieser Alarm in der Leitstelle ein. Normalerweise.

Sobald Sie alarmiert werden: wer entscheidet, wie viele Leute und LKWs mit wie vielen Anhängern in die Gefahrenzone geschickt werden und was von Ihrem Lager aufgeladen und transportiert wird?

Die Erstalarmierung ist wirklich so ausgelegt, dass alles rasch passieren muss, vor allem, wenn man in Richtung Blackout denkt, wo man nur 30 Minuten Zeit hat, die Telefonnetze zu nutzen und SMSen zu verschicken. Das heißt wichtig ist eine schnelle Erstreaktion und deswegen passiert das ohne großes Nachfragen nach Führungskräften durch die Leitstellendisponenten. Die nehmen sich den Landeseinsatzplan und schauen nach, und sagen beispielweise: es ist ein Haus eingestürzt, Anzahl x Verletzte, ich muss diese Einheiten alarmieren; und dann tun sie das und die Einheiten rücken ein oder sie werden voralarmiert. Das heißt sie wissen, dass sie sich bereitmachen oder sie rücken dann in die definierte Dienststelle ein. Das ist die Erstalarmierung, die passiert einmal. Dann gibt es bei uns immer einen höchst im Dienst befindlichen Offizier, der Hauptinspektionsoffizier, das ist sehr analog zur Feuerwehr. Das ist eine Person, die den Landesrettungskommandanten, der unser höchster Kommandant ist, vertritt. Der ist 24 Stunden, 7 Tage die Woche erreichbar und diese Rolle hat Entscheidungskompetenz. Bei keinem Katastrophenszenario wird diese Erstalarmierung 100 Prozent passen. Wir machen jedoch trotzdem die Erstalarmierung und dann ist das Lageverfahren und das Führungsverfahren einzuhalten: Lage evaluieren, durchführen, kontrollieren, nachbessern. Aber das ist das, was unsere Führungskräfte lernen und in ihrer langen Ausbildung mitbekommen. Es ist in keinem Plan abdeckbar, was weiter passiert.

Die Leitstelle muss dann die Zieloptimierung einsetzen?

Die Leitstelle ist dann das operative Element, der Hauptinspektionsoffizier wird dann in der Leitstelle sitzen oder vor Ort sein und sagt, ob er mehr Einheiten oder eine Ablöse für die Einheiten braucht. Oder er sagt, dass doch nicht so viel passiert ist und er weniger Einheiten braucht. Diese Optimierung in diesem Führungskreislauf, die passiert dann wirklich durch eine Führungskraft; operativ – das kommt jetzt auf die Tageszeit und die Größe an. Wenn es ein Großunfall war, zwei Autobusse mit 60 oder 70 Verletzten, dann wird das die Leistelle abdecken. Wenn es was Größeres ist, nehmen wir die Flüchtlingskrise voriges Jahr her, dann wird ein Stab eingerichtet. Aber der Stab ist nicht innerhalb von einer Stunde bereit zu arbeiten, das dauert schon ein paar Stunden, bis da wirklich was Produktives rauskommen kann. Die müssen sich in die Situation einarbeiten und dann kann man die Entscheidungsgrundlagen für den Einsatzleiter entwickeln. Dann ist es natürlich auch so, dass dieser HIO, der Hauptinspektionsoffizier, auch durch in der Regel einen anderen HIO abgelöst werden muss, wenn es etwas Längeres ist.

In der Theorie zur Katastrophenlogistik ist der Faktor Kosten natürlich nie der Wichtigste, dennoch werden sie meist berücksichtigt. Gerade beim Wiener Roten Kreuz, wo alles über Spenden finanziert wird und die Mittel sicher begrenzt sind, müssen Kosten auch eine Rolle spielen. Inwiefern?

In manchen Bundesländern wird die Katastrophe ausgerufen. Im Wien gibt es das Wiener Krisen- und Katastrophenmanagementgesetz und wenn eben gewisse Kriterien eintreten, dann ist es eine Katastrophe und dann ist eine Vergütung im Gesetz geregelt. Das ist gerade ein schwieriges Thema. Freiwillige, überhaupt unsere Spezialisten: wenn die eine Offiziersausbildung machen reden wir von einer Ausbildungsdauer von 6 bis 10 Jahren, je nach Geschwindigkeit natürlich. Aber unter 10 Jahren aktiver Mitarbeit und Ausbildung ist es schwer zu wissen, wie alles läuft. Leute brauchen Ausrüstung, brauchen Weiterbildung, wir brauchen ein Gebäude, wo wir sie schulen können, wo wir das Material lagern können, das heißt es sind enorme Kosten da. Das ist jetzt in anderen Bundesländern wieder anders mit dem Rettungseuro etc., oder wo das Rote Kreuz fix diverse Aufgaben von einem Land übernimmt, da gibt es diverse Förderungen, die ich jetzt aber nicht konkret kenne.

Ich nehme jetzt als Beispiel wieder eine Überflutung, weil es durch die Medien das Thema ist, über das in dem Zusammenhang am Häufigsten berichtet wird. Ich weiß nicht, wie viele andere Katastrophen, abgesehen von Überflutungen und Murenabgängen, in Österreich hauptsächlich vorkommen.

Das, was in den letzten 10 bis 12 Jahren immer wieder passiert ist, waren die zwei hundertjährigen Hochwässer und das ist natürlich von der Katastrophenhilfe gesehen eines der größeren Dinge. Obwohl man sagt, Blackout ist das Wahrscheinlichste.

Das Thema Blackout wurde von meinem ersten Interviewpartner auch angesprochen.

Ja, das ist ein Thema wo man sagt, man kann sehr viele Punkte abdecken. Das hilft einem auch wirklich breiter zu denken. Wenn wir über Verbesserungspotenziale reden: Wir wurden durch das Thema Blackout auch sensibilisiert. Vor 5 oder 6 Jahren wurde es in Wien auch vom Bürgermeister beauftragt, da hat sich die Stadt wirklich sehr intensiv damit beschäftigt. Was kann man – was kann man nicht. Da ist irrsinnig viel passiert in den letzten Jahren. Das war auch ein Kriterium, dass wir hier einen zweiten Standort haben. Wir waren früher nur in der Nottendorfer Gasse *(Anm. der Verfasserin: im 3. Wiener Gemeindebezirk)*, daneben ist dieses Kühlhaus, eines der größten Österreichs und da gab es einen Ammoniakaustritt. Unser Standort war genau in der Reichweite der Gefahrenzone. Das heißt es konnten keine Kräfte nachrücken. Der Wind war für uns in die richtige Richtung. Wenn der Wind in die andere Richtung gegangen wäre, hätten bei uns keine Kräfte einrücken können. Ein Großteil des Materials wäre in der Sperrzone gewesen. Deswegen haben wir gesagt, man muss sich das wohl leisten – nein man will es sich leisten – dass wir bei solchen größeren Ereignissen trotzdem noch funktionieren. Deswegen ist dieser Standort hier damals geschaffen worden.

Waren Sie sich dessen bewusst, dass das passieren könnte?

Naja, gewusst hat man es immer. Das war eine Frage des Sich-Leisten-Könnens. Es muss schon so sein, dass es wirtschaftlich auch was bringt. Wir haben gesagt, wenn dieser Standort ausfällt und ich habe nichts mehr, dann muss das Unternehmen entscheiden: macht es wirtschaftlich Sinn, einen zweiten Standort etwas weiter weg aufzumachen oder nicht. Wir sagen immer „über der Donau“, also die zwei Standorte sind etwas weiter voneinander getrennt. Das müsste schon ein ganz großer Unfall sein, dass beide Standorte gleichzeitig ausfallen. Beim Thema Blackout wäre es so, dass beide ausfallen würden. Bei uns nicht: im Standort Nottendorfer Gasse würde alles weiterlaufen, dort brauchen wir uns um und selbst nicht zu kümmern, das läuft alles weiter. Wir sind dort für mehrere Tage stromversorgt. Durch Altlast, weil das Gebäude damals gekauft wurde, war ein riesengroßer Tank für die Haustankstelle da und der wurde damals belassen. Wir haben damals nicht gedacht, dass man das braucht aber durch die Blackout-Planungen hat man gesagt, der Tank bleibt immer soweit befüllt –

da ist auch das Notstromaggregat angeschlossen – dass wir für mehrere Tage autark sind, inklusive dem Fahrbetrieb für die zirka 100 Fahrzeuge auf der Straße. Mehrere Tage lang brauchen wir keine externe Tankstelle, haben das Haus hell erleuchtet und der Betrieb läuft dort weiter. Ähnlich ist es hier, hier sind wir aus Kostengründen bei 7 Tagen. Treibstoff ist natürlich auch wahnsinnig teuer. Wir brauchen Spezialtreibstoff, weil normaler Diesel hält ja nur 3 Monate, bevor er abläuft und durch den Biodiesel-Anteil Klumpen bildet. Also darum brauchen wir uns einmal nicht kümmern, das ist schon ein wesentlicher Punkt bei dem Thema Verbesserung. Weil wenn ich selbst nicht einsatzbereit bin, wenn die Tore nicht aufgehen, wenn ich aufgrund des elektronischen Schließsystems nicht mehr ins Haus komme, wenn ich kein Licht oder keine Heizung habe, dann fällt alles aus und ich verliere schon enorm wichtige Zeit. Und darum brauchen wir uns nicht zu kümmern. Wir kommen her – wenn wir es schaffen im Blackout-Fall – und wenn wir einmal da sind, können wir sofort anfangen zu arbeiten. Das erspart schon einmal viel, was mit Optimierung zu tun hat, denn ich spare mir die Selbsthilfe. Das ist ein Ergebnis vom Blackout.

Zurück zum Hochwasser. Ich gehe davon aus, dass im Fall der Fälle das oberste Ziel ist, so viele Menschen wie möglich aus der Gefahrenzone zu retten bzw. so vielen Menschen wie möglich zu helfen und dies zwar unter Berücksichtigung der Kosten, aber diese sind dabei nicht das oberste Ziel.

Dass man so vielen Menschen wie möglich hilft, ist klar. Jenen, die das größte Leid haben – und das sind unsere Grundsätze – wird von der Priorität her zuerst geholfen, also den Schutzbedürftigsten. Ob es jetzt Ziel ist, die Leute schnell aus der Zone raus zu bringen, kann ich jetzt nicht sagen, das kommt auf die Situation an. Das entscheidet die Feuerwehr. Jetzt kommen wir zum zweiten Fall einer wahrscheinlichen Katastrophe in Österreich, nämlich zu den Murenabgängen. In irgendeinem Tiroler Seitental – und das soll jetzt in keinem Fall abwertend klingen – trifft es die Leute weniger, wenn irgendeine Zufahrtsstraße des Tals verschüttet wird. Die haben alle Lebensmittel und Getränke für zwei Wochen zuhause, heizen mit dem Ofen, denen ist das „wurscht“, wenn zwei Wochen keine Infrastruktur da ist. Die kommen über die Runden. Wäre es in Wien, müsste man die Leute wohin bringen. Auch bei Hochwasser: ist es hinter den Schutzdämmen, die man auch vor 2, 3 Jahren immer in den Bildern gesehen hat, wo die Donau mit dem mobilen Schutzdamm abgeschottet ist und daneben steht ein Mann und mäht gerade seinen Rasen, der ist zwar in der Gefahrenzone, lebt aber sein normales

Leben weiter. Die Leute in Steyr sind das gewohnt, dass ein- bis zweimal im Jahr das Erdgeschoß unter Wasser steht. Die werden auch nicht aus der Gefahrenzone gebracht. Das kommt also auf die Gegend und die Situation an. Wo wir stark sind, wie schon erwähnt Unterkunft, Betreuung, Camp und für Optimierung und Zielerreichung sind die Kräfte vom Team Österreich. *(Anmerkung der Verfasserin: Im August 2007 hat das Rote Kreuz gemeinsam mit Ö3 das Team Österreich gegründet, für das sich jede Bürgerin und jeder Bürger registrieren kann, um nach Katastrophen freiwillig zu helfen. Ziel dieser Aktion ist es, bereits im Vorfeld eine Kanalisierung herbeizuführen, damit in Notsituationen schnell und effizient Helferinnen und Helfer eingesetzt werden können.)* Die ersten Ideen dazu kamen nach dem großen Hochwasser 2002 und im Jahr 2007 ist das Team Österreich dann gegründet worden und die Idee war, diesen Katastrophentourismus rauszubringen. Es ist so ziemlich das Schlimmste für eine Region, die überschwemmt ist, wenn ein System, das sich vielleicht selbst noch erhalten kann, zerstört wird. Dann kommen irrsinnig viele Helfer mit dem Auto, versperren vielleicht die Zufahrtswege für die Rettungskräfte, kommen wirklich mit bestem Willen und wollen helfen, kaufen dort aber die Lebensmittel und Getränke auf, weil sie Hunger und Durst haben und blockieren das System. Dieses Unkoordinierte ist sehr schwierig, das versucht man mit dem Team Österreich wegzubekommen und das ist eine gute Sache. Die Leute werden minimalst geschult, sind kein Mitglied, haben keine Verpflichtungen beim Roten Kreuz, bekommen eine Schulung, wie dieser Alarm abläuft und gerade bei den Hochwassern, hauptsächlich bei den Aufräumarbeiten, ist das eine irre Stütze. Das heißt wir setzen die Leute, weil auch die Ausbildung und Ausrüstung fehlt, in der Regel nicht ein um Schutzwälle zu bauen, sondern wirklich nachher. Einerseits können sie beim Schlamm wegräumen helfen, was schnell gehen muss und das tun sie auch. Was wir immer machen sind auch Spendenaktionen, die Helfer sitzen dann am Telefon und nehmen die ORF-Spendentelefonate entgegen. Was auch immer wieder anfällt, ist die Sammlung von Großspenden. Da werden dann auch Telefone besetzt, wenn Spenden eingehen und die Koordination dieser Groß- und Kleinspenden läuft auch über diese Mitarbeiter. Das ist natürlich schon eine Optimierung, weil das bindet mir zwei ausgebildete Rotes Kreuz Mitarbeiter und die können mir dann 20 bis 40 Arbeitskräfte oder Mitarbeiter führen. Hätte ich dieses Optimierungspotenzial nicht, müsste ich dort ausgebildete Führungskräfte hinsetzen.

Also für das Team Österreich kann sich jeder und jede anmelden und helfen und wenn der Fall eintritt, werde ich informiert, dass ich gebraucht werde.

Genau. Da trägt man sich in einer Datenbank ein, gibt die Kontaktdaten und Fähigkeiten ein. Da wird sehr viel abgefragt. In der Flüchtlingshilfe hat uns das geholfen. Da konnten wir wirklich sagen, dass wir einen Dolmetscher für Farsi brauchen und das gibt man an und hat ein irres Potenzial von ich glaube mittlerweile um die 10.000 Personen, auf die wir auch aus dem Raum Wien zugreifen können mit nahezu allen Professionen. Das ist gerade in der Flüchtlingshilfe in punkto Optimierungspotenzial eine irre Ressource. Die Mitarbeiter unterstehen der Führung des Roten Kreuzes, müssen sich mit unseren Grundsätzen identifizieren, dass zum Beispiel kein Unterschied in der Hilfe gemacht wird und wirklich nur die momentane Bedürftigkeit eine Rolle spielt und es ist nicht immer optimal, aber es ist koordiniert. Zurückkommend auf das Hochwasser: wie damals vor 2 oder 3 Jahren – durch die Flüchtlingshilfe fehlt ein Jahr in unserem Gedächtnis – das Hochwasser im Bereich Tulln, Krems und Melk war, hat die ÖBB auch Sonderzüge zur Verfügung gestellt, damals vom Westbahnhof, und wir haben die Leute mit Sonderzügen dort gratis hingebracht. In einem Zug waren dann 200 Personen drinnen, 10 bis 20 Rotes Kreuz Mitarbeiter, die die Organisation übernehmen. Die werden dort hingebracht und den örtlichen Einsatzleitungen unterstellt. Die Person vor Ort weiß auch, dass 200 Leute in Zehnergruppen geführt kommen und der disponiert dann nicht die einzelnen Leute, sondern unsere Einheiten, wie wir sie zur Verfügung stellen. Die Person sagt dann, welche Gruppe bei welcher Straße anfängt und das ist dann wirklich eine Unterstützung.

Bereitet man sich aktuell schon auf einen nächsten Flüchtlingsansturm vor? Erwartet man nochmal annähernd so viele Flüchtlinge, wie im letzten Jahr?

Wir haben damals innerhalb von kurzer Zeit 120 Leute für die Notquartiere angestellt. Da haben wir fast bei allen die Befristungen wieder auslaufen lassen müssen. Da gibt es nur noch ganz wenige Leute bei uns im Haus. Das Wissen, das Knowledge ist da, ja. Natürlich, unser Kernthema ist immer noch Unterbringung, Betreuung, Camp, Verpflegung und das können wir und das werden wir auch wieder machen, wenn es nochmal soweit kommt.

In Wien gibt es ja in dem Bereich Katastrophenhilfe auch das Bundesheer. Herrscht hier eine Art Konkurrenzdenken oder arbeitet man hier zusammen?

Das ist ein Zusammenarbeiten. Das Bundesheer kann ja laut Gesetz auch nur aktiv werden, wenn ein Assistenzeinsatz angefordert wird und die priorisieren auch noch. Es könnte jeder Landes- oder Bezirkshauptmann Assistenzeinsatz anfordern und wenn das natürlich in dreißig Gemeinden oder Bezirken der Fall wäre, müssen sie auch priorisieren, wo sie helfen. Aber es ist ein Miteinander. Einerseits in Niederösterreich die Feuerwehr – und die Rollen sind ja auch getrennt. Die Feuerwehr sind die, die wirklich in der Gefahrenzone frei räumen und mit schweren Geräten arbeiten und Team Österreich ist dann eine Unterstützung, aber das ist keine Konkurrenz. Genauso mit dem Bundesheer und Militär. Auch wieder in der Flüchtlingshilfe; jeder hat seinen Teil getan und ohne dem geht es nicht. Nein – keine Konkurrenz.

Haben Sie Erfahrung mit internationalen Einsätzen?

Ich habe im Jahr 2012 die Situation nach dem Erdbeben auf den Philippinen sehr intensiv erlebt auf der Insel Bohol, dort ist das Rote Kreuz auch ganz schön stark. Ich war kurz nach dem Erdbeben dort auf einem geplanten privaten Besuch. Dort ist es schon auch – ich vergleiche es immer gern mit der Verwundbarkeit oder mit der Resilienz, also der Widerstandskraft – schwierig. Ich muss wieder auf das Thema Blackout zurückkommen. Es gibt in Indien oder Lateinamerika immer wieder viele Blackouts, auch über Tage. Das sind Riesengeschichten und die Leute trifft das ganz anders, das ist nicht vergleichbar mit uns. Auch auf den Philippinen. Nach diesem Erdbeben gab es wochenlang keinen Strom. Aber das ist dort nicht so ein Thema wie bei uns, weil die Leute so autark sind und alle haben ihren Holzvorrat und kochen mit Holz. Ich will nicht sagen, dass es dort egal ist, aber die überleben auch ohne Strom. Wir sind da ganz anders getroffen. Die sind es gewohnt, dass man die Sachen, überhaupt in den ärmeren Regionen, nicht nachkaufen kann. Das gibt es dann dort einfach nicht. Wir sind da viel verwundbarer im Vergleich zu solchen Naturereignissen. In Wien wäre das problematisch, wenn zwei Wochen der Strom weg wäre. Die Hygiene ist dort schon auf einem gewissen Niveau, die ist haltbar. Bei uns halt nicht, weil sie auf einem ganz anderen Level ist.

Sie waren nach dem Erdbeben privat auf den Philippinen. Wie war dort die Lage?

Es war interessant. Wir haben dort ein Haus, dort hat sich – laienhaft ausgedrückt – auf einer Seite die ganze Insel abgesenkt. Also da sieht man wirklich, durch die Häuser und durch die Swimmingpools geht eine Linie und dort ist es gebrochen. Laienhaft erklärt – vielleicht ist es geologisch gar nicht so. Seither steht auch das Haus bei jeder größeren Welle unter Wasser. Dort sind alte Kirchen eingestürzt, die hundert Jahre alt waren und schon viele Erdbeben miterlebt und überlebt haben. Also dort ist recht viel eingestürzt und die haben dort interessanter Weise auch – natürlich haben sie auch

Notstromaggregate – kleine Inseln eingerichtet; meistens bei der Gemeinde. Das war auch der Infopoint, dort gab es immer die News – klassische Katastrophenhilfe. Was man bei uns oft verlernt oder nicht so ausdrückt, aber dort gibt es die Information, dort kommt man einmal am Tag hin und erfährt alles. Die neuesten Nachrichten, weil das Internet und das Telefon ja auch nicht funktionieren, wo es Hilfe gibt, wo kann man Hilfsgüter abholen und dort kann man auch das Handy anstecken und wieder aufladen. Denn das ist eine der Sachen, die am raschesten aufgebaut wurde – das Handynetz. Ich weiß jetzt nicht warum, aber das Mobilfunknetz hat recht bald wieder funktioniert, viel schneller als der Strom. Das wird man bei uns auch brauchen nur wird es da schwieriger werden. Es gibt ja in Berlin in Deutschland das Projekt „Leuchtturm“, wo es auch bei Blackout darum geht, Stellen einzurichten, an die sich die Leute wenden können. Ich sage immer ein wenig abgeleitet davon: alle unsere notstromversorgten Außenstellen sind Leuchttürme. Da werden die Leute sowieso hinkommen. Spätestens wenn es kalt wäre oder die Lebensmittel ausgehen. Wir sind notstromversorgt und die Leute werden wohl kommen – also ich würde es machen. Gerade Krankenhäuser, das Rote Kreuz oder andere Rettungsorganisationen – die Hilfe wird ja dort überall angeboten. Bei uns wird immer wieder ein Blackout-Szenario angesprochen, aber das Projekt selbst ist noch nicht so kommuniziert beziehungsweise gibt es so noch nicht.

Anschließend wurde mir ein Landeseinsatzplan mit den angesprochenen Kategorisierungen gezeigt:

Das ist ein kleines Dokument, den Landeseinsatzplan gibt es in allen Kommandofahrzeugen und Leitstellen, auch elektronisch auf einem Stick und natürlich auch im Intranet. Es gibt auch Teile als Handy-App. Da ist jetzt alles beschrieben und das Elementare ist die Einsatzklassifizierung. Wir sagen nicht „es war ein Erdbeben“, denn das ist ja keine Aussage. Es kann ja bei einem Erdbeben etwas passiert sein oder nicht. Uns geht es darum, ist ein Gebäude eingestürzt, ein Kindergarten, eine Schule…. Oder bei einem Autounfall: schöne Information, aber war es Autobus, war es ein PKW? Da gibt es eben diese drei Kategorien: gelb, orange und rot und die unterschiedlichen Szenarien dazu. Zum Beispiel bei einem Verkehrsunfall: Autobus, Massencrash auf der Straße, oder bei einer Evakuierung: was ist es? Ist es ein Hotel, da kommt wieder unser Unterkunft-/ Betreuungs-Thema vor, weil die Leute dann wohin müssen. Das war beim Ammoniak-Fall damals auch ein Einsatz. Da war auch ein Hotel – das Hotel Ibis vis-à-vis – das lag in der Gefahrenzone und die sind dann laut Plan mit einem Bus von den

Wiener Linien in ein Haus, das auch in der Stadt Wien vorrätig ist, hingebracht und versorgt worden. Bei Einsturz: Ist es ein Spital oder ein Schulgebäude? Wenn ein Reihenhaus einstürzt, werde ich nur Suchhunde und zwei oder drei Krankenwägen brauchen? Wenn ein Hotel oder eine Schule einstürzt, sieht das anders aus. Flugnotfall ist natürlich auch ein relevantes Thema. Es fliegen viele Flugzeuge über Wien, hoffentlich passiert nie etwas, aber sollte etwas sein, gibt es diese Kategorie hier auch.

Ist in diesem Zusammenhang schon mal etwas in Wien passiert?

Vor Jahren hat es eine kleine Bruchlandung gegeben, da ist einem Flugzeug der Treibstoff ausgegangen und die sind in Wien notgelandet. Aber in meiner aktiven Zeit hier ist noch nichts Derartiges passiert. Seuchen sind ein Punkt, da kommt wieder unser CBRN als Fachberatung vor. Terror ist ein großes Diskussionsthema; wann weiß ich, dass es ein Terrorangriff ist? Wie zum Beispiel in Nizza, der LKW, der dort durch die Strandpromenade gefahren ist; das weiß ich ja nicht gleich, dass das ein Amoklauf ist. Das könnte auch ein Herzinfarkt gewesen sein und er hat dadurch die Kontrolle über sein Fahrzeug verloren. Da geht es dann wieder auch um Selbstschutz. Wann schickt man Leute hin, gibt es Folgeanschläge? Das ist ein heikles Thema. Kategorie Unwetter, vom Erdrutsch bis zum Sturm. Wie gesagt, es kommt nirgends ein Erdbeben. Aber aus unserer Überzeugung ist das kein Einsatzkriterium. Dann die diversen biologischen und chemischen Unfälle und sonstige; zuletzt auch Blackout. Es sind immer die gleichen Szenarien, aber gelb, orange und rot unterscheiden die Parameter. In Kategorie gelb sind es drei oder vier Verletzte, in der mittleren Kategorie zwanzig Verletzte und in der Roten sind es dann abhängig vom Szenario fünfzig plus. Wenn wir uns zum Beispiel – immer mit dem Hintergedanken, dass es eine Berufsrettung und eine Berufsfeuerwehr gibt und dass wir bei solchen Sachen in der Regel nachalarmiert werden – die Kategorie Stau anschauen: Ungarn M1, wo vor ein oder zwei Jahren Leute im Stau eingeschneit waren. Ein lang anhaltender Stau mit extremen klimatischen Verhältnissen, hier eben Schnee. Was fragt die Leitstelle ab: Wie viele Betroffene? Was brauchen wir? Vielleicht sind alle in einem Autobus mit Toilette und Getränken, da werden sie nichts brauchen. Wie ist die Streckenbeschaffenheit? Was macht die Leitstelle jetzt, wenn sie diesen Alarm bekommt? Sie schauen auf den Einsatzplan und alarmieren in dem Fall nur den Hauptinspektionsoffizier. Weil da haben wir gesagt, da kann man nichts hinschicken, was typisch ist. Da muss jetzt der Hauptinspektionsoffizier, der oberste Einsatzleiter, sagen, was wir machen. Das war jetzt kein gutes Beispiel. Ich suche ein

Beispiel, das nicht ganz absurd ist, sondern wirklich bei uns vorkommen könnte. Einsturz von Bürogebäude: Wieder die Fragen: Wie viele Personen sind betroffen? Vielleicht war es in der Nacht und es ist keiner im Büro gewesen, dann haben wir dort nichts zu suchen, weil wir nichts zu tun haben. Dann muss die Feuerwehr oder eine Abrissfirma hin, um das Material zu beseitigen. Wir gehen jetzt davon aus, dass jemand betroffen ist. Dann stellt sich die Frage: Was ist der Betreuungsumfang? Vielleicht gehen auch alle nach Hause, weil rechtzeitig evakuiert wurde, dann haben wir auch nichts zu tun. Vielleicht sind aber noch einige drinnen gefangen. Automatisch wird hier eine MobSan geschickt. Eine MobSan sind fünf Rettungsfahrzeuge mit einem Kommandofahrzeug mit entsprechenden Sanitätern. Außerdem ein Verpflegsdienst, der Getränke hinbringt und nachher ein Löffelgericht, auch für die Einsatzkräfte, weil das länger dauern wird. Automatisch wird auch die Logistik alarmiert, irgendwas wird zu transportieren sein. Beispielsweise das Essen oder auch etwas Anderes, aber man wird sie auf alle Fälle brauchen und wenn es Personal ist, das transportiert werden muss. Eine mobile Beleuchtung kommt hin, wieder mit einem Anhänger. Da ist ein Teleskop oben und damit werden ein paar hundert Quadratmeter ausgeleuchtet. Unterkunft, Betreuung und Camp werden alarmiert. Bis die einrücken, dauert es meist dreißig bis vierzig Minuten, bis dahin weiß man schon mehr. Wird man die Leute in einem Gebäude unterbringen oder müssen wir mit den Zelten rausfahren. Der Hauptinspektionsoffizier wird natürlich auch alarmiert und in diesem Fall auch unsere Suchhunde, dafür sind sie ausgebildet. Teilweise werden Stellen auch nur voralarmiert, die rücken nicht sofort ein, sondern die machen sich bereit, für den Fall, dass sie einrücken müssen. Dieser Einsatzplan ist das Kernstück. Vieles wird auch dann ohne hier nachzuschlagen gemacht. Was ich aber immer mache, ist nachher das Ganze als Checkliste herzunehmen und zu schauen, ob ich etwas vergessen habe.

Also gibt es nach jedem Einsatz eine Kontrolle?

Ja, auch während dem Einsatz. Nach der Alarmierung muss ja alles schnell gehen. Wenn man als Hauptinspektionsoffizier gerade im Kino ist – der Alarm findet ja meist in der Freizeit statt – hat man den Plan selten mit. Dann läuft man zum Auto und schaut schnell nach, ob man wirklich alle Schritte eingehalten hat. Auch für die Dokumentation und eventuelle rechtliche Konsequenzen, falls man doch einmal eine falsche Entscheidung getroffen hat. Dann kann oder muss man beweisen, dass zu dem Zeitpunkt diese Lageinformation vorlag. Nachher weiß jeder alles besser. Im Einsatz muss alles dokumentiert sein. Nicht nur alles, was am Patienten getan wird muss dokumentiert sein, sondern auch jede Entscheidung muss dokumentiert sein. Wenn ich die Entscheidung treffe, wir gehen nach links und dort fallen alle wie die Lemminge in den Abgrund, muss ich nachher schon begründen, warum ich so gehandelt habe. Wenn auf dem rechten Weg eine Bombe zu explodieren drohte und die Feuerwehr gesagt hat, der linke Weg ist sicher, dann ist meine Entscheidung richtig. In dem Moment war das meine Lageinformation, ich hatte eine vertrauenswürdige Info und bin den Weg gegangen. Auch wieder bei der Flüchtlingshilfe. Jetzt könnte man sagen: Warum hat man dieses Haus aufgemacht, wenn man doch wusste, es zahlt keiner? Ja, weil zu dem Zeitpunkt die Leute nass, krank und barfuß da waren und man hätte sie in der Situation als Rotes Kreuz nicht stehen lassen können. Das ist sehr wichtig auch für das Verbesserungspotenzial. Also das Einsatztagebuch ist das Wichtigste, wo wir wenigstens minimal Entscheidungen dokumentiert werden und nachvollziehen können, wann wurde die Entscheidung auf Grundlage welcher Informationen getroffen. Das ist das Mindeste.

Das wird dann auch für die Zukunft verwendet?

Ja klar. Also nach dem Einsatz, wenn es etwas Kürzeres ist, haben wir auch ein Peer-System, das heißt Stressverarbeitung nach belastenden Einsätzen, um sich auch unter Kollegen aussprechen zu können, also das "Debriefing", sprich das Runterkommen nach dem Einsatz. Da wird dann das Psychische zuerst reingewaschen. Wenn mehr Hilfe gebraucht wird, wird mehr Hilfe angeboten, um dann wieder mit etwas Abstand – aber nicht zu viel – den Einsatz noch einmal evaluieren zu können. Was wurde gut gemacht, was wurde falsch gemacht und hoffentlich daraus lernen.

Das war ein schönes Schlusswort. Ich möchte mich wirklich bei Ihnen bedanken, dass Sie sich die Zeit für mich genommen haben.

11. Appendix D – Abstract English

Main objective of this thesis was to provide an overview about literature considering multi-objective optimization in disaster management and underline theoretical models with practical examples. As a basis for this review, the article by Gutjahr and Nolz (Gutjahr & Nolz, 2016) *Multicriteria optimization in humanitarian aid* is taken, selected articles are described in detail and two interviews with two experts from a governmental as well as a non-governmental organization in Austria were conducted, in order to examine if theory and practice are consistent. Findings show that in some points, theoretical models take into consideration important factors in real life. Although the interviews showed that the first objective to be fulfilled in real disaster situations is saving lives, some models focus on costs as one of their prioritized objectives. Nevertheless, it can be seen, that theoretical models and real disaster management kind of learn from each other. New models take into account new technology gained in real life disaster management, and disaster relief organizations are always interested in progress in optimization models in order to be able saving more lives and helping more people in need.

12. Appendix E – Abstract German

Das Ziel dieser Arbeit ist eine Übersicht und Zusammenfassung relevanter Literatur zum Thema multikriterielle Optimierung im Katastrophenmanagement. Basisliteratur ist der Artikel von Gutjahr and Nolz (Gutjahr & Nolz, 2016) *Multicriteria optimization in humanitarian aid* woraus nach bestimmten Kriterien Artikel ausgewählt und detailliert beschrieben wurden. Um dem theoretischen Teil der Arbeit praktisches Unterfutter zu liefern, wurden zwei Experteninterviews mit dem Österreichischen Bundesheer und dem Österreichischen Roten Kreuz durchgeführt. In einigen Punkten stimmen Theorie und Praxis sehr gut überein, allerdings bemisst die Fachliteratur dem Faktor der Kosten anscheinend eine weitaus größere Bedeutung, als es die beiden Interviewpartner in der Praxis wahrnehmen. Dennoch lässt sich erkennen, dass theoretische Modelle Neuerungen aus dem Katastrophenmanagement annehmen und in die jeweiligen Optimierungsmodelle einfließen lassen. Andererseits sind Hilfsorganisationen auch immer an Fortschritten und optimierten theoretischen Modellen interessiert, da dies wiederum die Basis für sie ist, mehr Menschenleben zu retten und mehr Personen in Not helfen.