EMPIRICAL RISK ANALYSIS OF HUMANITARIAN DEMINING FOR CHARACTERIZATION OF HAZARD SOURCES

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1 BACKGROUND AND OBJECTIVE

Even years after the end of armed conflicts unexploded ordnance (UXO) poses a serious threat to the civil population (see e.g. [1]). Efficient humanitarian demining is a prerequisite for the sustainable development of the affected regions (see e.g. [2]). To this end, the EU FP7-Security project “Demining toolbox for humanitarian clearing of large scale area from anti-personnel landmines and cluster munitions (D-BOX)” [3] improves and develops solutions for all phases of the humanitarian demining process.

The present paper aims at characterizing explosive hazard sources relevant for humanitarian demining. Different types of landmines, submunitions and fuzes are identified along with their associated frequency, damage and risk quantities.

2 METHODOLOGY

We focus on a database-driven analysis of hazard sources and their empirical risk assessment. For this we spot, collect and categorize publicly available historical-empirical data on humanitarian demining accidents and on explosive hazard sources. We identify hazard source attributes sufficient for empirical risk assessment. After pre-processing the collected data, we apply statistical methods and time series analyses.

First, we identify categories of hazard sources. To this end, we determine the absolute and relative distributions of the number of damaging events with respect to hazard source types. In a similar way, we determine the absolute and relative damage of hazard source types in terms of the distributions of different consequence types (injured and/or fatalities). With histograms, we compare hazard source types using annual event frequency, different consequence types, and risks for the consequence types.

Second, we further characterize the different hazard source types. We analyze the time evolution of the frequency, damage and risk quantities of the hazard source types. In few cases we find decreasing risks, i.e. a kind of learning curve. We apply common f-N and F-N curves using annual frequencies to assess the risks (see e.g. [4] and [5]) as well as modified f-N and F-N curves using relative frequencies. Furthermore, we compare the risks of different hazard sources and hazard source types with a 2D scatter chart similar to an f-N plot in which each hazard source is represented by a point and its location is determined by the severity of a consequence type and the annual event frequency. These approaches are used to further refine the hazard source characterization.

3 DATA GATHERING AND ANALYSIS

In search of publicly available historical-empirical data on humanitarian demining accidents and explosive hazard sources (especially landmines and submunitions) we find data sources which provide either data on UXO or data on demining accidents. The most comprehensive publicly available data sources for landmines and submunitions are Jane's Mines & EOD Operational Guide [6], the Collaborative Ordnance Data Repository [7], the Cluster Munitions Identification Tool [8], the Munitions Reference [9], the book Anti-Personnel Landmines [10], the private website LEXPEV [11], and Wikipedia [12], [13]. Regarding humanitarian demining accidents, the Database On Demining Accidents (DDAS) [14] is the only comprehensive data source which is publicly available.

Analyzing the data sources, we identify publicly available attributes of hazard sources required for the quantitative mine risk assessment, such as shape, dimensions, mass, casing material, explosive type, and explosive mass. For instance, those attributes can be used to quantify blast parameters with the help of simplified Kingery-Bulmash polynomials according to Swisdak [15] and to estimate initial fragment launching conditions using empirical-analytical methods, such as Gurney equations [16], Taylor angle [17] and Mott distribution [18]. Furthermore, we identify publicly available attributes of damaging events during humanitarian demining which suffice for an empirical risk analysis of hazard sources, such as name and type of mine, year of damaging event, number of victims (divided in injured and fatalities), country of damaging event, type and cause of damaging event, type and severity of injuries, and used protective equipment.

For an empirical risk analysis of humanitarian demining, the following categorization of hazard sources proves sufficient: anti-personnel (AP) blast mines, AP bounding fragmentation mines, AP fragmentation mines (including AP directional mines), anti-tank (AT) mines, submunitions, fuzes, and other UXO. The category other UXO includes all other ordnance which is rarely involved in recorded demining accidents, such as grenades, mortar bombs and improvised explosive devices. A pre-processing of the worldwide data on demining accidents gathered from the DDAS [14] is made accordingly before conducting an empirical risk analysis.

4 RESULTS OF EMPIRICAL RISK ANALYSIS

Figure 1 shows the relative distribution of the number of damaging events with respect to hazard source types as well as the damage in terms of the distributions of the two consequence types victims (i.e. injured plus fatalities) and fatalities. Most recorded demining accidents occur with AP blast mines since this is the most commonly used type of landmine. However, AP bounding fragmentation mines cause the most damage in terms of fatalities since they spread lethal high-velocity fragments at a height of 0.5 – 1.5 m above ground level in all directions leading to larger hazard areas.

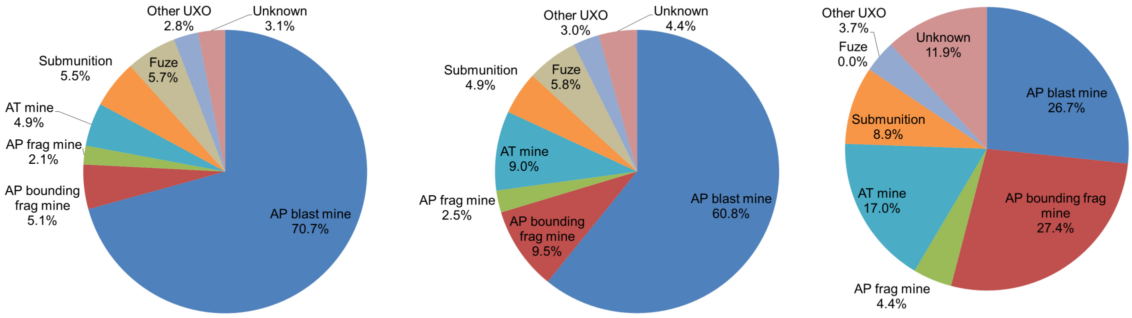

Figure 1: Relative distributions of the numbers of accidents (left), victims (center) and fatalities (right) with respect to hazard source types.

A comparison of hazard source types using absolute values of annual event frequency, different consequence types (injured and/or fatalities) and risks for the consequence types confirms the above result: see histograms in Figure 2 in the top left, top right and middle left. The risk scatter chart of Figure 2 in the middle right considers only hazard sources which were involved at least in three recorded demining accidents. For some hazard source types we identify characteristic areas within the risk scatter chart. AP blast mines usually show small consequences but can have high event frequencies. AT mines are associated with high consequences and low frequencies. AP bounding fragmentation mines position in between. Similar results are obtained from the common F-N curves in Figure 2 in the bottom left. The modified F-N curves in the bottom right give information on the distribution of the extent of damage in case of a damaging event. AP bounding fragmentation mines and AT mines show the greatest damage potential.

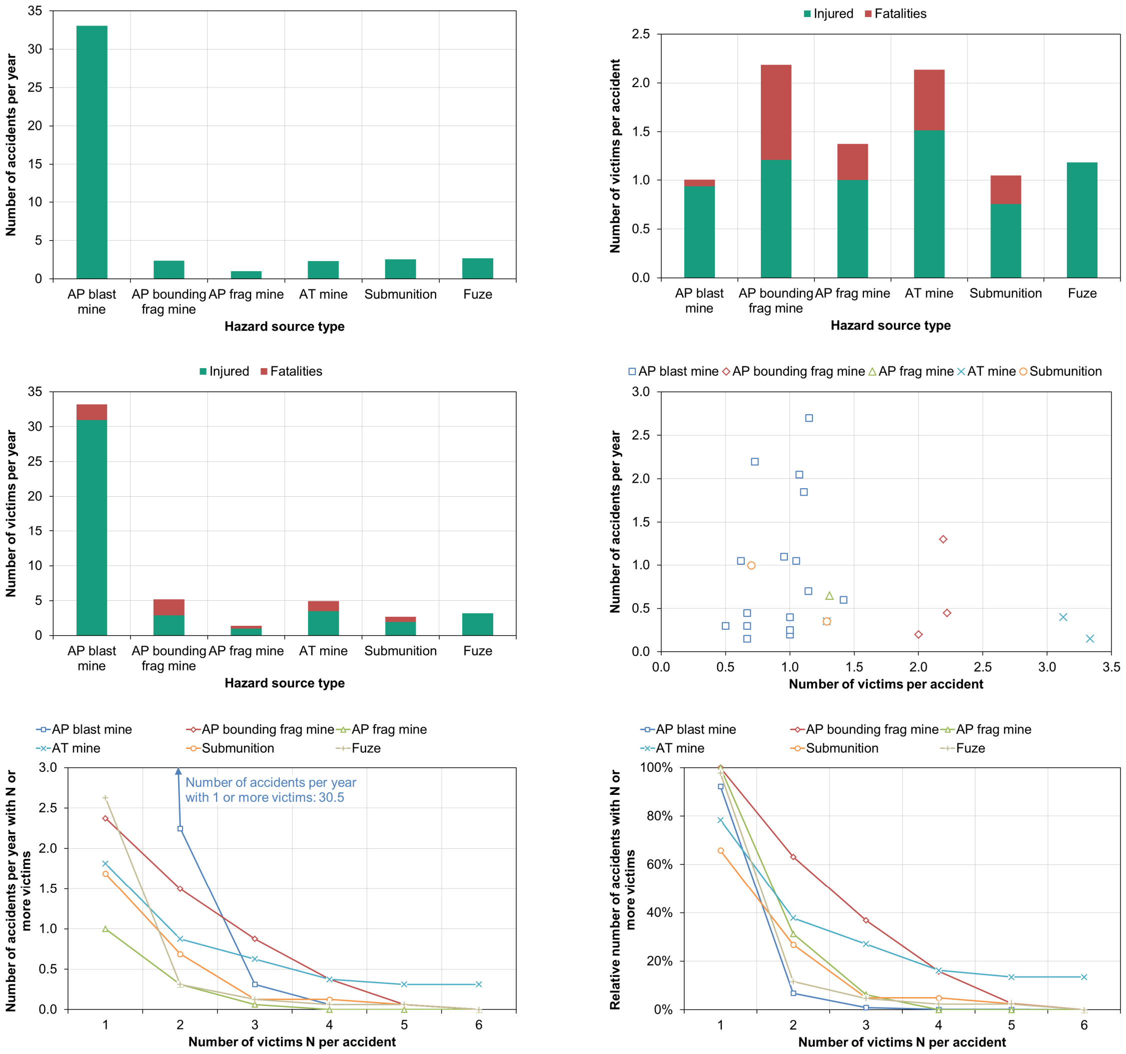

Figure 2: Comparison of hazard source types using frequency (top left), damage (top right) and risk quantities (middle left) as well as a risk scatter chart (middle right), common F-N curves (bottom left) and modified F-N curves (bottom right).

Analyzing the temporal evolutions of frequency, damage and risk quantities associated with the single hazard source types, we identify decreasing risks for few types like AT mines as illustrated in Figure 3. The risk decrease for AT mines primarily results not from a reduction of the event frequency (i.e. the annual number of damaging events) but from a considerably mitigation of the extent of damage (i.e. the number of victims per accident).

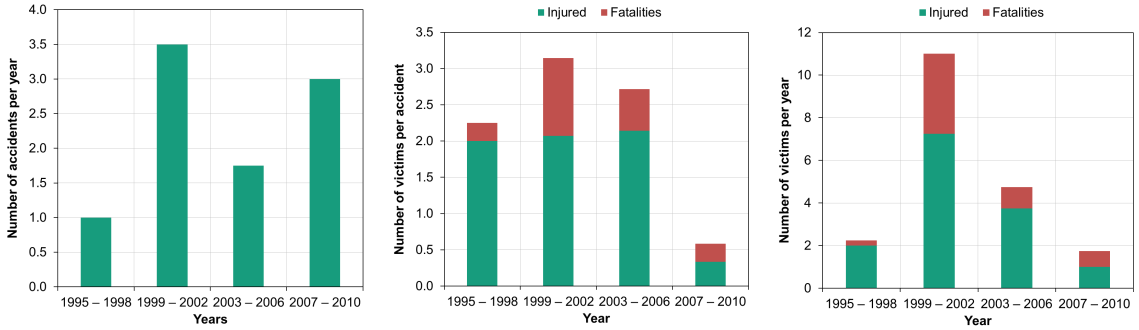

Figure 3: Temporal evolution of frequency (left), damage (center) and risk quantities (right) of AT mines.

With the help of the empirical risk analysis, we are able to confirm hazard source types as well as to identify those that pose the biggest threat for humanitarian demining: for example, AP blast mines because of high event frequencies, and AP bounding fragmentation mines and AT mines because of high consequences. If enough data is available, the above methods can be also applied to single hazard sources, countries, etc.

5 SUMMARY AND CONCLUSION

The present work focused on a database-driven analysis of hazard sources and their empirical risk assessment. We listed the most comprehensive publicly available data sources for landmines and submunitions and for humanitarian demining accidents. We showed which hazard source attributes suffice for the empirical risk assessment and how to categorize demining hazard sources. We provided examples how to apply statistical methods and time series analyses to historical-empirical data in order to assess different hazard sources or hazard source types. The empirical risk analysis identified different types of landmines, submunitions and fuzes along with their associated frequency, damage and risk quantities. Based on the analysis results, we identified hazard source types that pose the biggest threat for humanitarian demining.

The findings allow us to define and implement an interactive online database structure for explosive hazard sources which provides new attributes for the risk assessment and methods for the empirical risk analysis of humanitarian demining. In this context we also presented publicly accessible attributes that will be used for a quantitative mine risk assessment of the hazard sources. We believe that historical-empirically validated quantitative risk assessment has the potential to further improve a risk-aware humanitarian demining process.

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