Census-based multiple system estimation as an unbiased method of estimation of casualties' undercount[1]

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1. Introduction

There exist two major methodological approaches to estimating war casualties.[2] The first one is empirical counting of victims and is based on merging of (un)conventional sources on war deaths, such as records of exhumations, missing persons, war time death notifications, military and morgue records etc.; further excluding duplicates and overlap in order to produce the minimum count. This approach, sometimes called the passive surveillance method, obviously undercounts war victims, as not all deaths are recorded. The second approach relies on post-conflict, retrospective epidemiological surveys, which are often criticized for the fact that reliable samples cannot be easily drawn from survivors populations and this often leads to serious miss-estimation of victims.

In this paper, we first of all present our latest 2010 estimate of casualties of the 1992-95 war in Bosnia and Herzegovina (BH). This estimate is our final product; to become part of the ICTY archive at some point. We as well critically review the latest epidemiological estimate of BH war victims produced by Obermeyer et al. (2008). This estimate is a sample survey extrapolation based on data on sibling deaths collected in a retrospective WHO survey in 2002-2003. We argue that the epidemiological approach has a number of serious deficiencies and produced erroneous results for Bosnia and Herzegovina and likely for a number of other conflicts.

The 2010 ICTY estimate is an improvement of our 2005 number; the improvement relates to sources and the counting method we used and most importantly by applying a multiple system estimation (MSE) techniques for estimating the undercount on the victims' lists.

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[1] The views expressed in this paper are of the authors alone and do not necessarily express the views of the International Criminal Tribunal for the former Yugoslavia or the United Nations.

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[2] As a matter of fact, more approaches exist, including for example, excess deaths estimated as a residual category between two population projections, demographic balancing equations for the population loss/population decline during the conflict period, excess deaths estimated from mass grave records, excess deaths as a naïve estimate from a nation-wide investigation etc. (comp. Tabeau and Zwierzchowski, 2009). Sample survey extrapolations and empirical counting can be seen as the most essential approaches.

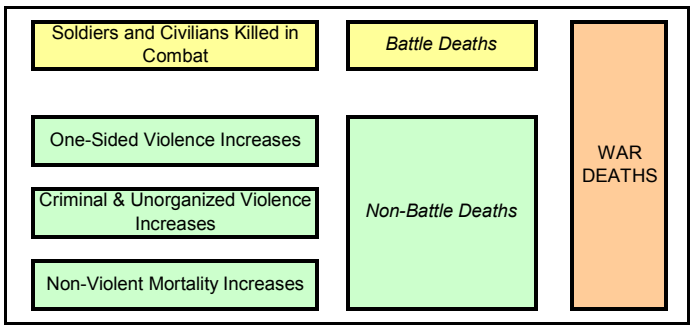
The MSE assumes perfect matching of sources on deaths. This condition is usually violated, as records of war victims often contain errors, precluding reliable and full matching of the sources leading to the overestimation of the undercount. In this paper we propose a modification of the "imperfect-matching" approach. The mortality sources are additionally matched with the pre-war population census of 1991. In this way, a vast majority of death records are validated. The overlap structure of the matched (thus, validated) records is transmitted onto the unmatched (not validated) records, that is records containing errors. In this way the perfect matching assumption is satisfied and the MSE undercount estimate is unbiased.

The new approach has been used to estimate the number of casualties of the 1992-1995 war in Bosnia and Herzegovina. All reliable lists of war related deaths, accessible to the OTP, ICTY, were used. The databases were matched with the 1991 Population Census (a mean matching rate of 90%). Additionally the lists were matched with each other and the overlap structure was obtained. Some 89,186 unique death records were extracted as the minimum number and the undercount was estimated at 15,546 (with the 95% confidence interval of 14,092 to 17,494), resulting in the total number of casualties of 104,732, which is consistent with the previous ICTY estimate. Has the correction of overlap not been used, the undercount estimate would equal 78,240, and the total number of war related deaths - 167,426, which seems highly overestimated.

Note that in our paper "war deaths" (or equivalently "death toll") denote generally the sum of two categories proposed by Lacina and Gleditsch (2005): their "battle deaths" (i.e. deaths in combat of both soldiers and civilians) and their "one-sided violence increases" (non-combat deaths of civilians and soldiers, including mass violence victims). The term "war deaths" is therefore different in our paper than the same term used by Lacina and Gleditsch (2005), who by "war deaths" describe four categories: "battle deaths", "one-sided violence increases", "criminal and unorganized violence increases", and "non-violent mortality increases". [3]

Occasionally, for victims of the siege of Sarajevo and Mostar, several cases of accidental falls, gas explosions, drowning, and other accidents were included in our death toll as war deaths too, due to rather straightforward links of these deaths with fighting and chaos and destruction brought by the war. Generally, however, we were not counting non-violent mortality increases (i.e. indirect deaths) as war deaths. Many such deaths are likely reported in our sources but it is impossible to distinguish them from natural deaths. Finally, our soldiers (or, equivalently, military deaths) are not identical with the "battle deaths" of Lacina

[3] Sources of war deaths (Lacina and Gleditsch, 2005; their Figure 1)



and Gleditsch. Our category of soldiers covers combat and non-combat deaths of all those individuals that were in the army (ABiH for Bosniaks, HVO for Croats, or VRS for Serbs) or were associated in some way with the FBiH or RS Ministries of Defense.

This paper comprises the following sections:

1. Introduction
2. The 2010 ICTY Estimate: Methods
3. The 2010 ICTY Estimate: Sources
4. Estimation of the Undercount in the 2010 ICTY Estimate
    a) Dual System Estimation
    b) Census-Based Multiple System Estimation
5. The 2010 ICTY Estimate: Main Results
6. Discussion

2. The 2010 ICTY Estimate: Methods

Our approach to estimate death toll in Bosnia and Herzegovina is a reconstruction of war-related deaths. As previously (comp. Tabeau and Bijak, 2005), our goal was to collect *all* war-related death records from the territory of Bosnia and Herzegovina in the years 1992-95. Only individual-level sources were used; our sources included official death notifications, military records, missing persons lists, exhumation and (DNA) identification records, and some unconventional sources. Witness statements, press reports, morgue records were *not* considered. The names and other details of the deceased allowed for elimination of duplicates within each source and for comparing the sources in order to exclude the overlapping records. Another reason for using individual records was the need of confirmation of persons' identities and their survival status. The 1991 population census served as the basis for the validation of personal details of the deceased. The 1997/98 and 2000 registers of voters served to verify the reliability of reporting of disappearances or deaths. This was done to exclude *false positives*, i.e. cases where persons reported as dead or missing might have survived the conflict, as indicated by the fact that they appear on the electoral rolls from the post-war period. Having eliminated the duplicates, overlap, and inconsistent cases, we made a list of individuals whose deaths took place in Bosnia and Herzegovina in the period from April 1992 to December 1995 and were all war-related (most of them in a direct way; some indirectly). The list was used for producing statistics such as the minimum and overall number of war-related deaths in Bosnia, or the number of victims by sex, ethnicity, and military status.

The approach we applied for producing the 2010 count of war-related deaths can be summarized as follows:

- Individual-level records were used;
- Mortality sources were required to contain information on personal details of the deceased/disappeared and the date, place, and cause of death/disappearance,
- The identity of the deceased was confirmed through a verification procedure in which each mortality source was cross-examined against the 1991 population census,

- False positives were eliminated through matching of death/disappearance records with sources on survivors (voters registers 1997/98 and 2000),
- Duplicates within and overlap between sources were excluded,
- Definition of ethnicity was kept the same; i.e. as reported in the 1991 census; this was possible by establishing links between the census records and records from mortality sources,
- Definition of military versus civilian status was consistent with reporting in military sources; all records from the military lists were taken as soldiers and the remaining records as civilians. This approach is not equivalent to distinguishing between combat and non-combat casualties.

As mentioned before, we matched information about individuals from the 1991 census with records of these individuals from other sources. When comparing various lists with data on individuals we used the MS Access database managing system to search for records on one list that match records on the other list. If key variables are identical in two lists the matched records are assumed to represent the same person, otherwise not.

Matching two lists always started with searching for records with identical personal identification numbers (if available), names and date of birth. Only exceptionally would two different persons have identical names and be born on exactly the same date, especially if we only consider the population of a limited area, such as a single municipality. Quite often, however, names are spelled differently or the date of birth is recorded slightly differently – or missing altogether in one or both lists. Consequently, for persons not matched in the first round we make the search criteria gradually broader for one or more variables, for example by including only the year (and not the full date) of birth, or only the initial of the first name, in addition to the surname. The results of such matches have, however, to be inspected visually before deciding whether different records are likely to refer to the same person or not, by looking at other available information, such as the municipality and place of birth or residence. For difficult cases we checked the 1991 census for additional information, e.g. information about family members of the person in question.

The final matching rate with the census had been improved in the 2010 analysis; at present it is about 90% of the original source death records that are linked with the census. So, some 10% of the records reported in the original source are ‘lost’ and would remain excluded from the minimum numbers. In the 2010 analysis, we modified our method in order not to lose the unmatched records. Next to the matching of each mortality source with the 1991 census, we merged our mortality sources directly, (thus not through the census), and eliminated the overlap of mortality sources through a direct analysis of merged data.

3. The 2010 ICTY Estimate: Sources

The sources selected for our casualty estimate are an essential element of the method. We believe that the reliability of these sources is relatively high and their coverage is large, yet still incomplete. The reliability of the sources is fairly satisfactory, although it is not comparable with that of regular statistical sources. Our sources cover particularly well a

number of major episodes of the Bosnia war: the 1992 initial conflict in the Autonomous Region of Krajina and at the Eastern border with Serbia, the 1993-94 conflict in Herzeg-Bosnia and in Mostar, the 1992-1995 siege of Sarajevo, and the pre-1995 episodes in and the 1995 fall of Srebrenica. War-related deaths from the territory controlled by the VRS (the army of Republika Srpska) are now well represented in our sources. The major RS source, deaths registered in the local vital events offices, is now available and included in our integrated sources. A considerable improvement was also obtained by incorporating the latest OTP inventory of the exhumation and identification records.

We used the following mortality sources in producing our 2010 estimate of war-related deaths in Bosnia (duplicates excluded):

- The FIS Mortality Database, 1992-1995, established by the Federal Institute for Statistics (FIS) in Sarajevo through a centralization and computerization of individual death records available from the vital events registration system in the territory of the Federation of Bosnia and Herzegovina. Coverage: 74,402 death records from the FBH territory, of which about 26,000 are war-related.
- The RS Mortality Database, 1992-1995, established by the statistical authority of Republika Srpska in Banja Luka and similar to that of the FIS Mortality Database. It contains information collected from the relatives of the deceased through the standardized form of death notification (DEM-2). Records consist of personal information (JMBG, names, DoB, PoB etc.) and of information about the death (DoD, PoD, CoD etc.). For about 43,000 records death certificates are available. The war-related deaths (a minimum of 11,000 flagged) and the natural and accidental deaths are included. Coverage: approximately 66,000 deaths records from the RS territory, of which about 15,600 war related.
- The Herzeg-Bosna death registries; about 1,300 death records related to the conflict in the Herzeg-Bosna area (in Mostar in particular).
- Military records of fallen soldiers of the BH Government Army (ABiH), 1992-95. Acquired in 2001 from the Ministry of Defense of the Federation of Bosnia and Herzegovina. Coverage: about 34,000 records from entire country; all war-related.
- Military records of fallen soldiers of the Republika Srpska Army (VRS), 1992-95. Acquired in 2001 from the Ministry of Defense of Republika Srpska. Coverage: 14,300 records from entire country; all war-related.
- Military records of fallen soldiers of the Croatian Defense Council (HVO), 1992-95. Acquired in 2002 from the Ministry of Defense of the Federation of Bosnia and Herzegovina. Coverage: approximately 6,700 records from entire country; all war-related.
- The ICRC lists of Missing Persons for Bosnia and Herzegovina, 1992-1995, established by the International Committee of Red Cross. The list was acquired in mid-2009. It contains records of persons of ever reported missing. A large number of them have been identified so far and are presented by ICRC as closed cases of known deaths. Coverage: 22,000 records of persons confirmed dead or still missing; entire country, all war-related.

- The ICMP[4] list of Srebrenica missing identified through DNA matching, mid-2009 edition. Approximately 6,500 records.
- Exhumation records of the identified bodies from the FBH Commission for Tracing Missing Persons; Status as of early 2009. Coverage: 10,500 records from mass graves on the RS territory, all war-related.
- The HSS-94 Mortality Database, 1992-1994, (HSS-94 stands for the Households Survey of Sarajevo conducted in mid-1994); established at the OTP (ICTY) in 2002 from the original survey questionnaires collected in mid-1994 through interviewing of approximately 85,000 households (equivalent to about 340,000 persons) living at that time on the territory within the front lines in Sarajevo. The survey was designed and completed by the Research Institute for War Crimes and International Law in Sarajevo. Coverage: 12,860 death records, of which 7,900 are war-related; the within-front-lines territory of Sarajevo as of mid-1994, its population coverage was close to complete (as in the population census).
- The MAG Mortality Database of War Victims, 1992-95, established by a non-governmental Bosnian organization Muslims against Genocide (MAG).[5] First acquired in 1998, the latest version of the MAG database supplemented at the OTP in 2003. Coverage: about 34,300 records of dead and missing persons from the entire country, all war-related.
- *Knjiga nestalih općine Prijedor* (Prijedor Municipality Book of Missing, KNP). Coverage: more than 3,000 records acquired in 1998, supplemented in 2001, all war-related.

In addition to the above sources on deaths, we also used a number of reference sources on Bosnia and Herzegovina population including:
- Population Census, 1991: 4,4 million records
- OSCE Voters Register, 1997 and 1998 (merged): 2.8 million records
- OSCE Voters Register, 2000: 2.5 million records

The major improvement in our 2010 estimate is that it is based on more sources, includes the latest up-dates of some sources used previously, and that the direct approach of integrating the mortality sources was applied instead of the indirect approach used previously. In 2005 mortality sources were merged together through the population census (thus indirectly). In this procedure the unmatched records were "lost". In order to compensate for this, a correction was made in our 2005 estimate by dividing the minimum numbers of deaths from each mortality source (i.e. the matched records) by the source-specific matching rates. Such correction is no more needed in our 2010 approach. By merging all mortality sources directly, and by direct search and elimination of the overlap of these sources, no records are lost.

[4] ICMP stands for the International Commission for Missing Persons, which is an international organization based in Sarajevo mandated to identify, through DNA matching, human remains exhumed from mass graves in Bosnia and Herzegovina. The Srebrenica list of ICMP largely overlaps with the ICRC Srebrenica list; only about 500 ICMP records are additional.

[5] The MAG database has been up-dated and expanded by the BH Commission for Gathering Facts about War Crimes, which recently changed their name and status (from governmental to non-governmental). The commission is known now as the Research and Documentation Centre in Sarajevo. Mirsad Tokača has been in charge of this project. He presented the RDC final results on the death toll in 2007.

The new/updated sources we used include the RS Mortality database, official death notifications from the Herceg-Bosna region, the ICMP records of Srebrenica victims, the 2009 ICRC list of missing persons for Bosnia and Herzegovina, and the latest 2009 OTP inventory of exhumation records. Our 2010 list of sources is most certainly more complete that that of 2005; yet some components are still missing. For example, records of exhumed and identified persons are still incomplete. ICMP estimated recently (14 September 2009)[6] that so far 12,621 missing persons from Bosnia and Herzegovina have been identified on the DNA matching basis out of approximately 30,000 BH missing persons altogether. Our records of missing persons (about 27,600) are fewer than 30,000; as there exist records of the missing persons that are unique to ICMP, our list can be further expanded by these additional records.

Some sources on victims of the Herceg-Bosna conflict 1993-94, such as the Mostar War Hospital (about 470 death records), were not directly included in our 2010 estimate; these victims are represented mainly in FIS, Mostar death registries, and fallen soldiers records. Records of the Serb victims collected by the Serb NGO "Istina" from Pale were not taken (3,005; mostly Sarajevo victims). Death records from the RS Commission for War Crimes were not processed too (6,039). Finally, several lists of victims published in local newspapers in Bosnia and Herzegovina were not processed in our 2010 estimate (e.g. the 37-(A4) page list of victims of the siege of Sarajevo from the *Dani* magazine, published 6 April 2002; perhaps 12,000 or more victims). Reporting in these sources is not as good as in the sources included in the 2010 estimate; most records from these sources would not be matched with the census and search for duplicates would not be successful leading to the over-estimation of the death toll.

The final reason for the incompleteness of our 2010 estimate is that all sources included in our analysis are partly incomplete, but it is hard to assess in what extent. Moreover, sources such as FIS and RS Mortality databases contain large numbers of records with unknown causes of death (16,450 and 14,813 cases, respectively). Of these cases, although they are *not* flagged as war-related, some 5,739 records overlap with the war victim records from other sources in our integrated BH database. It is likely more cases of war victims are still among the FIS and RS records with unknown cause of death but at this stage we cannot include them in our analysis. A similar situation relates to the Bakije burial records (originally 11,522 war time records from Sarajevo; no cause of death reported); some 5,015 records overlap with other sources on war victims; the remaining Bakije records cannot be included as no flagging is possible of whether or not these deaths were war related.

For the above reasons, our 2010 estimate must be seen as a minimum. The improvement between the 2005 and 2010 estimates is enormous though; today about 89,186 records of excess deaths from the 1992-95 war in Bosnia and Herzegovina can be individually documented (comp. Table 1), as compared with 67,530 (corrected 80,868) in the 2005 estimate. The progress is unquestionably significant. The 89,186 documented war deaths is a

[6] Compare the ICMP article "ICMP makes highest number of DNA-assisted identifications in the world" available at: http://www.ic-mp.org/press-releases/icmp-makes-highest-number-of-dna-assisted-identifications-in-the-world-icmp-putem-dnk-ostvario-najveci-broj-identifikacija-na-svijetu-icmp-realiza-el-mayor-numero-de-identificaciones-por-adn-en-el-mun/

minimum. We estimate that the underestimation rate equals approximately 14.8 percent and the overall number of victims is about 104,732 persons (comp. Section 4).

Table 1. Estimated overall Numbers of War-Related Deaths from Bosnia and Herzegovina in 1992-95, Status as of 10 October 2009

Source Priority	Source Name	Source Size (Overlap Contained)	Source Size (Overlap Excluded)	Matching Rates with 1991 Census (Overlap Contained)	Matching Rates with 1991 Census (Overlap Excluded)
1	FIS Mortality Database	26,326	26,008	92.2%	92.3%
1	RS Mortality Database	15,573	15,261	82.2%	82.2%
1	Mostar Death Notifications	1,348	1,151	68.0%	63.7%
2	Lists of Fallen Soldiers	54,065	27,765	91.9%	90.3%
3	ICRC 2009 Combined	21,885	10,353	90.3%	83.3%
4	Exhumations 2009 Merged	10,458	2,140	92.3%	76.9%
5	Sarajevo Household Survey	7,874	1,681	86.9%	58.1%
6	MAG 2002	34,316	4,788	87.9%	43.3%
7	Knjiga Nestalih Prijedor	3,143	685	87.7%	57.2%
8	ICMP Srebrenica Identified	6,489	49	95.8%	18.4%
#	**Total**	**181,477**	**89,881***	**89,53%**	**84.1%**

** The total of 89,881 unique records has two components: 89,186 deaths strictly related to the BH territory and war period and 695 deaths not strictly related to these two requirements (e.g. war deaths outside the former Yugoslavia and/or the war period). All deaths are of BH citizens.*

The basis for the under-estimation rate of 14.8% is the Multiple System Estimation we applied to study the completeness of our integrated BH database. It is discussed in Section 4.

Table 1 summarizes the source input for our estimate. We used twelve large data sources,[7] grouped into 8 categories, which jointly contained 181,477 death records. Some of these records represented at this stage the same persons. Only after the elimination of the duplicates and source overlap, unique cases of different deaths (or disappearances) remained in our database (i.e. the integrated BH database). The number of such unique records is 89,881 cases of which 89,186 represent war deaths falling on the BH territory (with a few in the neighboring countries – former Yugoslav republics) and in the war period of April 1992 to December 1995. All of them are documented by the available personal and death details of the deceased.

The grouping of sources was introduced to ensure that the categories were internally complementary and externally independent; some dependencies remained, however, and are discussed in Section 4. The blocks are labeled with the same numbers as in Table 1. For example, category 1 comprises all official death notifications from 1992-95, i.e. FIS and RS Mortality Databases, and Mostar death notifications; category 2 is a merge of all three military lists (VRS, ABiH and HVO). The next categories correspond with single sources. Placing the ICMP list as the last category is related to the fact that any ICMP record contains only a general (and not specific) information about the place and date of death/disappearance; these records do not significantly improve the reporting of the same cases in other more detailed mortality sources.

[7] The lists of fallen soldiers (source number 2) comprise lists for the three armies : ABiH, VRS and HVO.

4. Estimation of the Undercount in the 2010 ICTY Estimate

4.1 Dual-System Estimation

For the reasons discussed in the previous section, we are convinced that the 89,186 documented cases is a minimum death toll. In order to estimated the missing cases we initially performed a simple variant of capture-recapture method for two groups of sources that can be considered independent: the Household Survey Sarajevo-1994 and the rest of the Integrated BH Database.[8] In this method, the overlap of independent sources is analyzed in order to estimate the unknown overall number of excess deaths.

The dual system estimation or capture – recapture method is applied when we deal with a population of unknown size and our task is to estimate the total number of members of this population. We do this in two steps. First, we randomly select a sample from this population, mark all captured individuals, put them back to the original population and allow them to mix up with the rest of the population. Every individual should have the same probability of being captured as the others. In the second step we select a next random sample. The two samples should be drawn independently. Thus, the probability that an individual is re-captured in sample 2 has nothing to do with the fact, whether or not it was captured and marked in sample 1. Having selected the second sample, we count the re-captured individuals in it. Note that the "re-captured" individuals are those of all captured in sample 2 who previously were also captured (and marked) in sample 1. The underlying principle of the dual system estimation method is that the share of re-captured individuals in sample 2 estimates the share of captured (and marked) individuals from sample 1 in the whole population. Because the number of marked individuals in the whole population is known (from step 1) and also the estimated share of the marked individuals in the population is known (from step 2), we can calculate the total number of individuals in the population. We do this by dividing the number of marked individuals by their estimated share in the population.

If N denotes the total number of individuals in the population, p is the estimated share of all marked individuals in the population (i.e. the share of re-captured individuals in the second sample), and N_1 is the number of individuals marked in step 1 (i.e. those captured in sample 1), we obtain[9]:

$$\hat{N} = \frac{N_1}{p}. \qquad (1)$$

If N_2 is the number of individuals in the second sample and N_{12} for the number of re-captured individuals from the second sample (i.e. those also captured and marked in the first sample) we get, that:

[8] HSS-94 contains as well a few hundreds of deaths from outside the siege of Sarajevo. While comparing HSS-94 with the remaining sources in our integrated BH database, the victims of the siege of Sarajevo are the main component of our estimating of the undercount and the death records from other parts of Bosnia and Herzegovina contribute less. We assumed the undercount is similar for Sarajevo victims and victims of other episodes in Bosnia. Note the siege of Sarajevo is very well covered in our sources and therefore the undercount estimated in this way is relatively low.

[9] A hat above X means that it is an estimated value.

$$p = \frac{N_{12}}{N_2}. \quad (2)$$

The estimated total size of the population can be therefore also expressed as:

$$\hat{N} = \frac{N_1 N_2}{N_{12}}. \quad (3)$$

The variance of the estimator is given by the equation:

$$Var(\hat{N}) = \frac{N_1 N_2 (N_1 - N_{12})(N_2 - N_{12})}{N_{12}^2 (N_{12} - 1)}. \quad (4)$$

All this reasoning makes sense if the samples are large as is the overlap between both samples (i.e. the number of re-captured individuals in the second sample)[10].

Our objective was to estimate the total number of killed or missing persons in Bosnia and Herzegovina during the 1992-95 war. We had two samples at our disposal, the 1994 Household Survey of Sarajevo (*HSS-1994*) and the *remainder* of our integrated BH database on war victims. We consider the two sources as independent samples of captured war victims. The sources were large and there existed a significant overlap between them. We considered HSS-1994 as the first sample and all records from HSS-1994 as captured and marked. The *remainder* of the integrated BH database was considered the second sample. (Note, that it makes no difference which source is chosen as "first" and which as "second"; the problem is symmetric.) We then counted the "re-captured" records in the *remainder* of the integrated BH database. This means that we measured the overlap of the two sources. Under the realistic assumption that both sources were created independently[11], we recalled that the share of "re-captured" records in the *remainder* of the integrated BH database is the same as the share of "captured" records (from HSS-1994) in the whole population and applied Equation 3 to obtain the total number of killed persons.

Samples 1 and 2 (i.e. our sources) are characterized below:

Table 2. Size and Overlap of Sources Used for Capture-Recapture Estimation of the Overall Total of Persons Killed or Disappeared in the 1992-95 War in Bosnia and Herzegovina

Killed or Disappeared Persons Identified in:	
HSS-1994:	7,363 (N_1),
Remainder of the Integrated BH Database:	88,256 (N_2),
Overlap:	6,433 (N_{12}).

In order to estimate the total number of persons killed or disappeared in the 1992-95 war in Bosnia and Herzegovina, the *capture – recapture* method was applied. The estimator of this

[10] What is "large" or "small" is quite subjective, but we will not discuss this case, while our samples are bigger than 7000, which is definitely not small.

[11] The independence of sources means that the fact, that a record is reported in HSS-1994, does not change the chance of being included in the integrated BH database, and *vice-versa*.

total was given by the equation (3). Using the data given in Table 2 we obtained the total number of deaths (killings and disappearances) equal $\hat{N} = 101{,}015$ and $SD(\hat{N}) = 431$.

We also produced a confidence interval for this estimator. The interval displayed below contains with the probability of 95% the unknown total number of victims:

$$\left(\hat{N} - 1.96 * SD(\hat{N}); \hat{N} + 1.96 * SD(\hat{N})\right)$$

In our case it means, that:

P (100,170 < N < 101,860) = 0.95,

and the total number of killed or disappeared persons in the 1992-95 war in BH is (with the probability of 95%) between 100,170 and 101,860 victims.

Realizing that the number of documented cases is 89,186, the undercount can be obtained as the difference between the estimated overall death toll (101,015) and the documented death toll (89,186) which equals 11,829 victims (or about 12% of the estimated overall total). This undercount and the estimated total must be seen as clearly low, *too low*, due to the very thorough coverage of the Sarajevo victims in our sources. The dual system estimation gives, however, a rough indication about the expected scale of the unknown undercount. This lead us to the conclusion that more information about the source overlap structure needs to be used in the estimation of undercount. As matter of fact we integrated 12 sources in our database and posses extremely complex knowledge of source overlap. The method allowing for utilizing this kind of knowledge for a high number of sources is the multiple system estimation (MSE), or in other words log-linear models for counts.

However, the dual system estimation method was additionally used in order to determine pair-wise dependencies between sources. This allowed us to better understand their nature and verify our *a priori* knowledge of sources. Table 3 below presents estimates of the total number of BH war victims obtained by the dual system estimation method, when different pairs of sources are used as capture opportunities.

Table 3. Results of Dual Capture-Recapture Estimations: Total Number of War Victims[12]

Source	1	2	3	4	5	6	7	8
1	42,413	86,497	196,840	150,966	69,685	91,370	443,694	180,168
2		53,328	118,827	125,102	106,166	85,517	1,042,076	71,594
3			21,850	35,467	483,193	108,126	40,872	22,338
4				10,390	172,324	91,496	22,156	23,008
5					7,364	41,111	2,859,994	22,773,170
6						32,715	101,544	111,361
7							3,107	Independent
8								6,185

Note: The source categories in Table 1 are associated with the following sources:

1. *Official death notification (FIS Mortality Database, RS Mortality Database, Mostar 1993 collection of deaths)*
2. *Lists of Fallen Soldiers (VRS, ABiH and HVO Lists of Fallen Soldiers and Other Military Personnel)*

[12] Column and row head numbers represent sources as in Table 1.

3. *ICRC missing person list*
4. *CTMP Exhumation Database*
5. *Sarajevo Household Survey*
6. *The MAG 2002 Collection*
7. *Knjiga Nestalih Prijedor*
8. *ICMP Identified Srebrenica Victims*

Certain pairs of sources produce reasonable and similar estimates of the total number of victims. These are FIS/RS/Mostar (1) and MAG 2002 (6), Soldiers Lists (2) and ICRC (3), Soldiers Lists (2) and Exhumations (4), Soldiers Lists (2) and SHS (5), ICRC (3) and MAG 2002 (6), CTMP Exhumations (4) and MAG 2002 (6), MAG 2002 (6) and Knjiga Nestalih Prijedor (7). It seems that these data sources are pair-wise independent.

The rest of pairs seem do be positively or negatively dependent. For instance the SHS (5) and the ICMP Identified Srebrenica Victims (8) pair of databases produced the number of victims of 22,773,170, which is five times higher then the entire Bosnian pre-war population. There is a very strong negative dependence between the two sources. SHS database contains records of persons living or having their close relatives in the Sarajevo area, while the ICMP Srebrenica Victims List contains records of the 1995 Srebrenica mass killing victims - an incident, which took place in a remote location.

Other pairs of negatively dependent sources are: FIS/RS/Mostar (1) and Knjiga Nestalih Prijedor (7), Soldiers Lists (2) and Knjiga Nestalih Prijedor (7), ICRC (3) and SHS (5). These dependences can be easily explained, knowing the nature of the data sources. The Knjiga Nestalih Prijedor (7) and the ICMP Identified Srebrenica Victims (8) are virtually independent, as there is no single common record on two lists, due to geographic and time separation of incidents covered by these sources.

Some pairs of data sources are positively dependent, as they produce numbers, which are significantly lower then the minimal number of victims - 89,186. These pairs are: FIS/RS/Mostar (1) and SHS (5), ICRC (3) and CTMP Exhumations (4), Knjiga Nestalih Prijedor (7) and ICRC (3), Knjiga Nestalih Prijedor (7) and CTMP Exhumations (4), SHS (5) and MAG 2002 (6).

The three sources ICRC (3), CTMP Exhumations (4) and Knjiga Nestalih Prijedor (7) are pairwise positively dependent as they all contain the same category of war victims – people who disappeared and died in the most tragic circumstances of the war; many of them have been found in the mass graves. FIS/RS/Mostar (1) and SHS (5) are positively dependent as the Sarajevo episode of the war was relatively well documented in the official death notification. The MAG 2002 (6) and the SHS (5) databases are positively dependent, as the centre of operations of the MAG was located in Sarajevo and victims from the Sarajevo area had the best coverage in the MAG 2002 collection.

4.2 Census-Based Multiple System Estimation

In order to deal with the multiple pair-wise dependencies among numerous sources and take advantage of a complex knowledge of the sources overlap, a Multiple System Estimation (MSE) framework was implemented. This method is immune to pair-wise dependencies of sources, as long as the sources coverage of war casualties is broad and comprehensive.

The MSE method uses a log-linear modeling framework for estimating the number of unobserved individuals. It regards empirical frequencies as independent Poisson observations. It was introduced by Fienberg (1972) and developed by Cormack (1989). The models were originally developed for use in wildlife population studies and later adopted for human populations, epidemiology and human right studies (compare IWGDMF, 1995). Ball et al. (2002) implemented this method in estimating the total number of war victims in Kosovo.

The MSE method requires data sources to be perfectly matched. This assumption can hardly be met by war mortality sources, which contain numerous errors precluding perfect match. This issue was addressed by matching death records with the 1991 Population Census (matching rate of 89.5% was obtained). There are good reasons to believe, that those remaining 10.5% of records that can not be matched with the Population Census contain errors. These errors certainly disturb the process of matching them with records from other sources on deaths and would cause overestimation of the total number of victims, as the sources would be under-matched. Therefore, the overlap structure[13] of unmatched records should be considered unreliable and only the overlap structure of matched, verified records should be used for estimation purposes. The overlap structure of validated records was therefore transmitted onto unverified records and the overlap structure of unverified records was forfeited. This was done by multiplying the empirical frequencies of overlap structures of all matched unique records by the factor of 1.18, that is the proportion of all unique records (89,186) to unique and validated records (75,532) and running the estimation using these frequencies.

The following specification of the MSE model is proposed:

$$\ln n_O = \gamma + \sum_i \beta_i * \mathrm{I}_{\{i\}} + \sum_j \sum_i IT_{ij} * \mathrm{I}_{\{i,j\}} + \sum_k \sum_j \sum_i IT_{ijk} * \mathrm{I}_{\{i,j,k\}} + \sum_l \sum_k \sum_j \sum_i IT_{ijkl} * I_{\{i,j,k,l\}}$$

Where:

O - is an overlap structure (set of sources containing given record, $O \subset \{1, 2, 3, 4, 5, 6, 7, 8\}$; compare Table 3)

n_O - is a number of records having overlap structure O (number of verified records multiplied by 1.18 in our case)

i, j, k, l – indices of data sources ($i, j, k, l \in \{1, 2, 3, 4, 5, 6, 7, 8\}$)

$$\mathrm{I}_A = \begin{cases} 1 \, if \; A \subset O \\ 0 \, if \; A \not\subset O \end{cases}$$

γ - is an intercept. In the proposed model specification it is equal $\ln\left(N \prod_{a=1}^{8} (1 - p_a) \right)$, which is a logarithm of an expected number of war victims that were not reported in any source – the expected value of the undercount. (p_a - is a probability that a randomly selected record is being listed by a data source a, where $a \in \{1, 2, 3, 4, 5, 6, 7, 8\}$)

[13] By overlap structure we understand all the data sources containing given record. Formally, for each record, the overlap structure is a set of indices of data sources containing that record.

β_i - is a parameter that characterizes the probability of a random record being contained by a data source i (Note: these parameters do not have a simple probability interpretation p_i, instead they are non-linear functions of p_i)

IT_{ij} - is a two factor interaction term of lists *i* and *j*, it measures how much the fact, that a given record is contained by a data source *i* modifies the probability of that record being contained by a data source *j*. Similarly, three and four factor interaction terms were added to the model.

Interaction terms are necessary to model complex dependencies among data sources. Using eight data blocks allows researcher to add interaction terms of up to 8 factors. However, the model with all two, three and four factor interaction terms is already over-fitted (meaning that reducing the number of variables does not significantly deteriorate model's fit to data). The parameters were estimated using the maximum likelihood (ML) method. A Chi-square goodness-of-fit test was used to assess how the model fits the data. "From general to specific" estimating approach was applied and all the three and four factor interaction terms, which proved to be statistically insignificant, were gradually dropped.

The number of observations is equal to the possible number of overlap structures minus one, as the number of persons who were not recorded by any source is unobservable (in this case number of observations is equal $8^2 - 1 = 255$)

The estimated undercount is equal to **15,546.** Standard error of the estimate is 936 and was computed using the method presented by Cormack (1993). The 95% confidence interval is (14,092; 17,494) under assumption of asymptotic log-normal distribution of the undercount or, alternatively, (13,816; 17,491) using the formula proposed by Chao (1989). The Pearson χ^2 =72.83 with 166 degrees of freedom (critical value is equal to 211.3; p-value $\cong 1$), meaning, that model fits data very well.

5. The 2010 ICTY Estimate: Results

In total, the 2010 Integrated BH Database contains 181,477 records, of which 163,060 records were matched with the 1991 Population Census (matching rate of 89.5%). After exclusion of the overlap, the 2010 Integrated BH Database comprises 89,186 valid and unique records, of which 75,532 records are matched with the 1991 Population Census (matching rate of 84.1%). Valid record is a record of a person, who died in Bosnia and Herzegovina during the 1992-1995 war and whose death was caused by war activities.

Table 4. Victims of the War in Bosnia and Herzegovina, 1992-95. Minimum War-Related Death Ratios By Ethnicity

Category/Ethnicity	Muslims	Serbs	Croats	Others	Total
Total Popualtion 1991	1,896,009	1,361,814	758,585	352,106	4,368,514
Killed/Disappeared	57,992	19,398	7,543	4,253	89,186
Percentage	3.1%	1.4%	1.0%	1.2%	2.0%

Note: Ethnicity of 13,654 unmatched records is estimated here based on the the ethnic make-up of the 75,532 records matched with the 1991 census

Figure 2. Minimum Numbers of Persons Killed in the 1992-95 War in Bosnia and Herzegovina, By Ethnicity

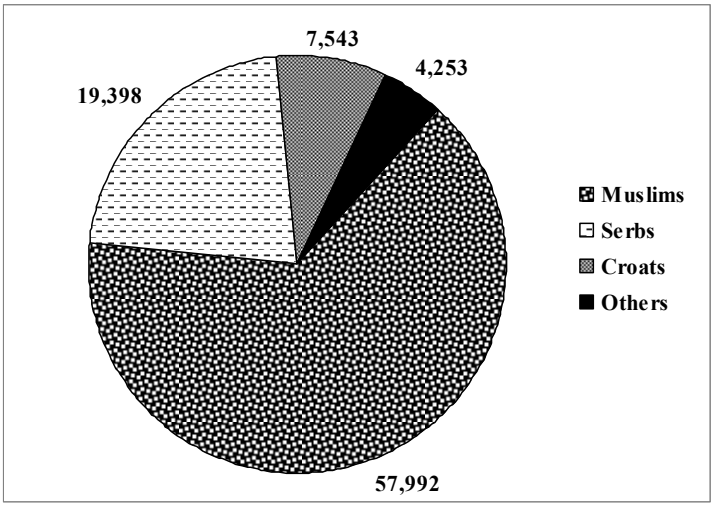


Figure 3. Victims of the War in Bosnia and Herzegovina, 1992-95. Minimum War-Related Death Ratios By Ethnicity

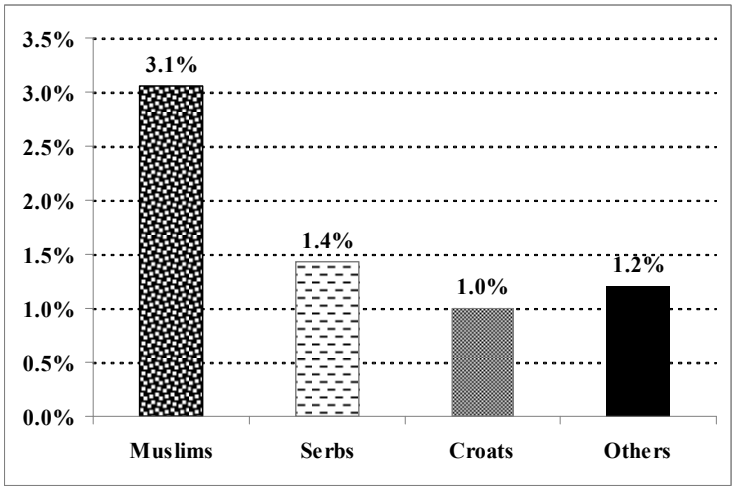


Table 4 and Figures 1 and 2 summarize the ethnic composition of the valid documented death/disappearance cases (89,186). The statistics from Table 4, Figures 1 and 2, and all other results in this section, should be seen as minimum numbers; they are dated as of 5 January 2010.

Compared with our 2005 estimate, the 2010 results are very similar. The overall death toll was estimated in 2005 to be 102,622 victims; according to our 2010 estimate it is 104,732 persons. Secondly, some increase is clearly seen in the ethnicity-specific absolute figures and death ratios. The general pattern remains, however, unchanged. Muslims suffered the greatest losses (3.1% of the 1991 census population). The losses of Serbs and Others are the second highest (1.4 and 1.2% respectively). Croats show the lowest losses of about 1 percent.

Table 5. Distribution of Victims, By Civilian-Military (C-M) Status and Sex

a) Overall Number of 104,732 War Deaths: C-M Status as in Matched Records

Military Status	Sex			Sex	
	Men	Women	Unknown	Total	Percent
Civilian	28,726	7,974	-	36,700	35.0%
Military	67,485	546	-	68,032	65.0%
Total	96,211	8,521	-	**104,732**	100.0%
Percent	91.9%	8.1%	-	100.0%	

Note: Percentage distribution into civilians and militaries as in the 75,532 war death records matched with the 1991 Census

b) Overall Number of 104,732 War Deaths: C-M Status as in Unique Records in the Database

Military Status	Sex			Sex	
	Men	Women	Unknown	Total	Percent
Civilian	32,251	9,842	13	42,106	40.2%
Military	62,099	526	1	62,626	59.8%
Total	94,350	10,368	14	**104,732**	100.0%
Percent	90.1%	9.9%	0.0%	100.0%	

Note: Percentage distribution into civilians and militaries as observed among the 89,186 war death records in the BH Integrated Database

The two next basic distributions available from our Integrated BH Database are the military-civilian and sex distributions; both can be given by ethnicity (comp. Tables 5 and 6).

Military-civilian statistics can be obtained from either the confirmed death records, i.e. those matched with the 1991 census (75,532), or all valid records in the database (89,186). The first approach is clearly conservative as unmatched records are rejected; these records are rejected because of (too many) deficiencies in reporting and/or recording deaths, which prevents us from declaring them matched. According to the first approach, about 35% of victims were civilians and 65% were militaries (Table 3a). If all unique records in the database are taken into account the civilian-military distribution is 40 versus 60 percent (Table 3b); the difference between the two is about 5 percent points and suggests the matching was more efficient for militaries than for civilians. This was because of rather thorough reporting of military deaths by the family members which was done for post-mortal benefits, thus based on documents containing personal and death details. Some military records were, however, of persons that were never in active combat; these were war-time deaths of the personnel of the (FBH and RS) Ministries of Defense, police forces, and employees of the army-related production sector; some families were allowed to register their deaths as military because of a (pre- or post-war) association of the deceased with the army or the BH government. All in all, we believe the percent of militaries obtained from the matched records might be an overestimation. The overall civilian-military distribution obtained from all valid records in the database (40:60) can be more realistic.

Another issue is that not all military deaths can be seen as combat deaths; the same can be said about civilians: not all civilian deaths occurred in non-combat situations (comp. Lacina and Gledish, 2005). Forensic evidence from exhumations indicates that several thousands of soldiers were murdered outside combat and their bodies found in mass graves; (this was particularly the case with the fall of Srebrenica in 1995). With regard to civilians, some were engaged in active combat during the siege of Sarajevo or Mostar, for example. A number of killed civilians must be as well regarded as collateral damage, thus as unavoidable legible

victims of war. For these reasons, the civilian-military distribution presented here cannot be taken as a measure of legible versus illegible victims of war. Our distribution is the best practical approximation of it; i.e. the legible (combat and collateral damage) and illegible (non-combat and mass violence) victims, but not the precise measure of it itself. The proxy is proposed in the absence of individual case-by-case data on circumstances of each death; for some victims we are able to reliably distinguish whether or not they were illegible war casualties but for many other victims we cannot do that. We often use our proxy in legal proceeding as a practical replacement of the distribution we are unable to produce. Note that the difference between the two cannot be seen as fundamental as only marginal numbers of victims would need to be shifted between the civilian-military categories in order to produce the required combat versus non-combat and collateral damage versus mass violence victims.

Our approach has been fiercely criticized by the supporters of high numbers of legible victims of the war in Bosnia and Herzegovina (see, for example, the discussion between Čekić and Tokača in Sarajevo on 18 October 2009; Bočanović, *Dani* 23 October 2009). However, as detailed descriptions of death circumstances are generally missing for the entire population of victims (unless witness statements are considered; some statements would contain such circumstances but they do not cover all death incidents in the war), our civilian-military distribution is the best we can offer at the level of the entire population.

In this paper we discuss the results from the matched records only (the more conservative variant). Note, however, that the sex and ethnicity distributions of civilians/soldiers are in both variants very similar.

Table 6. Distribution of Victims, By Civilian-Military Status, Sex and Ethnicity

a. Overall Number of 104,732 Victims

Military Status	Sex	Muslims	Serbs	Croats	Others	Total
Civilians	Men	19,715	6,299	1,230	1,482	28,726
Civilians	Women	5,894	1,181	445	453	7,974
Militaries	Men	42,162	15,225	7,084	3,014	67,485
Militaries	Women	330	73	98	44	546
Total	Total	68,101	22,779	8,858	4,995	104,732

Note: Percentage distribution into civilians and militaries as in the 75,532 war death records matched with the 1991 Census

b. Minimum Number of 89,186 Victims

Military Status	Sex	Muslims	Serbs	Croats	Others	Total
Civilians	Men	16,788	5,364	1,047	1,262	24,462
Civilians	Women	5,019	1,006	379	386	6,791
Militaries	Men	35,904	12,965	6,033	2,567	57,468
Militaries	Women	281	63	84	38	465
Total	Total	57,992	19,398	7,543	4,253	89,186

Note: Percentage distribution into civilians and militaries as in the 75,532 war death records matched with the 1991 Census

c. Percentage Distribution of Victims (both the Minimum and the Overall Numbers)

Military St:	Sex	Muslims	Serbs	Croats	Others	Total
Civilians	Men	68.6%	21.9%	4.3%	5.2%	100.0%
Civilians	Women	73.9%	14.8%	5.6%	5.7%	100.0%
Militaries	Men	62.5%	22.6%	10.5%	4.5%	100.0%
Militaries	Women	60.4%	13.5%	18.0%	8.1%	100.0%
Total	Total	65.0%	21.7%	8.5%	4.8%	100.0%

Note: Percentage distribution into civilians and militaries as in the 75,532 war death records matched with the 1991 Census

Overall about 92% of victims were men and 8% women (Table 5). Further, as already said, the conservative estimate is that 35% were civilians and 65% soldiers. Among civilians 78% were men and 22% women. (About 77% and 23% in the less conservative variant of civilian-military distribution). Among militaries, these proportions were 99% of men and 1% of women respectively (in both variants the same). (Table 5 a, b).

The ethnic distribution of victims is summarized in Table 6 a, b, and c. Some 65% were Muslims, 22% Serbs, 9% Croats and about 5% were Others. Slightly (but not fundamentally) different distributions are seen for civilians-militaries and men-women groups. Among civilians, generally higher (than 65%) proportion of Muslim victims is seen for every sex. For militaries this proportion is lower than 65% for every sex. The proportion of Serb victims is about 22% for the civilian and military men, and about 14% for the civilian and military women. The proportion of Croat victims is higher than the overall 9% for militaries (men and women), and lower than 9% for civilians. Others are represented at about 5% among civilians (both sexes) and among military men (more than 5% among military women).

6. Discussion

In recent years, several BH death toll estimates were presented based on a better foundation than the early (pre-2005) estimates. For example, Tabeau and Bijak (2005) and Tokača (2007) proposed approaches that in terms of sources and methods can be seen as far more reliable and better justified than the earlier attempts. Obermeyer et al. (2008) proposed an epidemiological estimate which at first seems sound source-wise and methodologically but in fact has several serious deficiencies.

Tabeau and Bijak's and Tokača's approach can be seen as a passive surveillance method. Both these approaches were developed to produce an overall count of excess deaths (or a minimum count if the overall total was impossible to obtain), a count that would be documented by individual records of the deceased, including among others their names, date of birth, ethnicity, civilian-military status, and date, place and cause of death. Passive surveillance methods utilize multiple sources, such as eyewitness statements, media reports, mortuary records, mass grave information, military records, war-time death notifications to the statically authorities etc., integrated with each other and sometimes with educated guesses in relation to the missing components in order to produce the required count. The main differences between these two approaches (Tabeau and Bijak, 2005, versus Tokača, 2007) are the sources used for obtaining the counts, the way of dealing with the integration of

sources, and the way of validating the candidate records of the deceased. In Tabeau and Bijak's approach, only the best selected sources are used for excess deaths estimation. Further, individual death records are cross-examined with the pre-war reference source on the BH population, i.e. the 1991 population census, in order to confirm personal details of the deceased, and to post-war sources on survivors in order to eliminate false positives. Finally, the integrated death records in Tabeau's approach are all linked back to their original sources; no editing of records is done. In Tokača's approach, all existing sources on war-related deaths are accepted. Records are not validated by cross-referencing them with the census and not with sources on post-war survivors. Finally, records are edited during the data entry process and evolve to become integrated multiple-source reports, which might be a risky procedure if the duplicate search module of the database is weak.

One of the latest estimates of BH victims was made in 2008 by Obermeyer et al. (2008). It is a survey-based extrapolation which the authors call a proportional mortality estimate. In brief, they estimated the fraction of excess deaths, (predominantly violent (direct) excess deaths), using survey data and applied this fraction to the UN Population Division estimates of total deaths available for all countries of the world from 1955 onwards, and for Bosnia and Herzegovina as well.[14] The survey Obermeyer et al. used for estimating the fractions of violent deaths was the 2002-2003 WHO world health survey, in which a retrospective module was attached regarding sibling death histories. The WHO survey was conducted in 70 countries of the world as nationally representative and designed to measure the population health and performance of the health care systems. For 45 countries information on adult deaths was collected with specific questions about the survival of siblings of the respondent, a randomly selected household member. Out of 45 surveys with data on siblings' histories, 13 countries reported more than five sibling deaths from war injuries in each given ten-year period. These countries were taken for a detailed analysis of war deaths. Bosnia and Herzegovina was one of the 13 countries. Countries with less than 5 war deaths per decade were rejected.

For Bosnia and Herzegovina, a sample of 1,028 households was selected with 4,095 siblings in the sample. The total of all sibling deaths in this sample was 619 (603 had year of birth reported), of which 111 were war deaths (105 had year of death reported). The sample was representative of the BH population at the time of the survey (2002-2003), but we have serious doubts as to its representativeness in terms of the population exposed to the 1992-95 war. Such samples are impossible to select due to massive out migration related to war, which makes it impossible to identify the sub-population actually exposed to subsequent war episodes. The second major known problem is that of under-representation in any post-war retrospective survey of the households that suffered the heaviest losses during the war.

The authors did correct the survey data for the under-representation of families with high mortality and secondly for (age) censoring. Their correction for the under-representation of high-mortality families did not compensate for the families that were killed/disappeared altogether. They estimated that based on the survey proportions of war deaths and using the

[14] The UN projections for the years 1992-95 are practically guesstimates as no sources are available even today on the war time population, its war-time births, deaths (natural and war-related), and migration.

UN estimated overall deaths in the years until 2002, the unknown overall number of (direct) excess deaths in the 1992-95 war in Bosnia was 176,000 with confidence interval of 67,000 to 305,000 deaths. For the period 1995-2002 alone their estimate was 56,000 direct war deaths; obviously an extremely high number realizing that the BH war ended in November 1995 and, thus, all 56,000 deaths must be associated with the year 1995. The historical background of the war in Bosnia and Herzegovina includes three major episodes in 1995: the fall of Srebrenica in July 1995 (about 8,000 victims), the end of the siege of Sarajevo (about 1,000 to 1,500 in 1995) and some deaths resulting from the military operations in the area of North-West Bosnia and Herzegovina (areas bordering with Croatia). It seems highly unlikely that the total of these deaths equaled 56,000 in this single year as compared with 120,000 violent war deaths in the years 1992 to 1994.

We find the Obermeyer's et al. estimate unrealistically high, which is partly because of the survey based frequencies of war deaths among the siblings and partly because of the UN projected population of Bosnia and Herzegovina during the war years 1992-95. Finally, we are not sure whether the authors controlled for the place of death required to by in BH. It is possible that deaths from other territories of the former Yugoslavia were as well reported by their respondents. Also deaths of migrants to third countries could have been reported; normally these deaths are excluded from the death toll in Bosnia.

Above all, it seems, however, the specificity of the sample is responsible for the high estimate Obermeyer et al. (2008) obtained. Spagat (2009) showed recently at the 2009 IUSSP population conference in Marrakesh that the selection mechanism of random samples can be responsible for both the under- and over-estimation of war victims due to the clustering of war deaths non-randomly among the population. When an overestimation is obtained it is likely for the estimation error to be relatively larger compared with the true victim number than if an underestimation is produced. In line with Spagat's conclusions, we generally believe random samples drawn from populations of survivors are not good representations of the victims' populations. It is because victims' families are underrepresented among survivors, and families killed in a whole are missing altogether. More importantly, conflict is not a random phenomenon, it is carefully planned and executed according to the plans; thus, the populations that happen to live where the strategic objectives are located are far more exposed to death and destruction than the populations outside these areas. Only samples taken from the populations exposed to the conflict, exactly following the exposure patterns during the conflict, could bring meaningful estimates. This is hardly possible as massive migration movements are usually associated with many contemporary conflicts and reconstructing the exposed populations is extremely difficult and often impossible. Thus, selecting a random sample from the population living 15 years after the war in Bosnia and Herzegovina and ensuring it representative of the entire BH population of 2002-2003 has very little (if anything) to do with a sample that would be representative of all conflict victims. As in other non-random processes, non-random sampling techniques, called convenience sampling, often bring more reliable results about victims number than random sampling methods.

Note, however, we most certainly do not disregard epidemiological methods as a possible estimation approach for war victims. Random sampling estimation, commonly used by epidemiologists must be applied according to the requirements of the problem. Multiple surveys representing a number of various war episodes need to be integrated in order to draw meaningful conclusions. The CRED estimates for Darfur (Sudan) by Guha-Sapir and

Degomme (2005) and Guha-Sapir et al. (2005), and most recently their up-date by Degomme and Guha-Sapir (2010) are examples of such a multiple-survey approach. Their results (those from 2005) were declared the most reliable among all the major casualty estimates for Darfur circulated up to the early 2006 by several major organizations and individuals who produced them. The estimates were assessed using several formal criteria by a group of experts called by the United States Government Accountability Office (GAO) who eventually produced a detailed report on the assessment (USA GAO, 2006). The studies by Guha-Sapir and Degomme are the recommended line for epidemiological research to follow in war victims estimation.

Contrary to the Darfur study by CRED, we find Obermeyer's et al. estimate extremely mechanical. Applying the same single-survey method to many contemporary conflicts does neglect the specificity of each conflict and each conflict-affected country. Applying it selectively to study international trends in conflict development, as Obermeyer et al. did it (they studied 13 countries with more than 5 conflict deaths per decade but rejected all conflicts with less than five conflict deaths), is biased and confusing. Conflicts are unique in terms of their duration, intensity, logic, warfare engaged, fairness, the exposed population, and in terms of the statistical culture and tradition in a given country, sources available, activity of international observers, aid organizations involved etc. All these factors contribute jointly to the picture of war and its victimization. Believing that the complexity of this picture can be obtained quickly in a single retrospective random survey run on the post-conflict populations of survivors is unjustified and wrong. Obermeyer et al. (2008) neglects all these factors; it is a mechanic uniform approach meant to produce as many estimates as possible. Obermeyer et al. (2008) do not improve our knowledge about victims of single conflicts and do not provide us with new insights about the conflict development in general (comp. Spagat et al (2009). Obermeyer et al. (2008) produced misleading and confusion that have not taken the estimation of global costs of conflict in the world any further.

Our new 2010 estimate is an improvement of the previous 2005 ICTY estimate by Tabeau and Bijak in terms of sources and counting methods used as well as estimating the unknown undercount of the overall number of casualties. The major improvement in our 2010 estimate is the undercount estimation. The Multiple System Estimation has been performed for 8 large groups of sources, not all of them being statistically independent and not all of them being perfectly matched. We dealt with these two major problems following the latest research results in the MSE field. We as well added our own contributions to solving the problem of imperfect matching; we extrapolated the source overlap structure obtained empirically for the death records matched with the 1991 census over the unmatched records and in this way satisfied the assumption of perfect matching rate among all analyzed sources. We realize that this step of the estimation, as several other steps of our method of empirical counting, cannot be easily reproduced for other conflicts. Nevertheless, the message we want to send with this paper is that in order to obtain stable results in the MSE approach, one has to ensure that the matching of sources is nearly complete. As in practice achieving the perfect matching rate of the sources on war victims is hardly possible, we suggest to use auxiliary information about the sources to make assumptions about the source overlap structure for unmatched records.

Finally, we realize that the source requirements of our empirical counting method are high (i.e. the availability of a pre-war census, post-war sources on survivors etc.), and cannot be

easily followed for any other conflict. Nevertheless, our message is that those interested in estimation of war victims should keep a number of important principles in mind:

- Conflicts are unique: The specificity of a conflict and conflict-affected country must be taken into account;
- Individual level sources should be used whenever possible;
- Biases of sources must be always assessed;
- Estimation of war victims must be based on multiple sources, cleaned from their biases and integrated together;
- Contrary to the research on social phenomena in peace time, formal and uniform approaches will not ensure comprehensive results on conflict trends and patterns;
- Thus, the assessment of global costs of conflict must be individualized.

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ANNEX. Estimation Results

Number of observations	255
LR chi2(88)	417862
Prob > chi2	0
Pseudo R2	0.9979
Log likelihood = -430.85657	

Variable	Coefficient	Std. Err.	z	P>z
β_1	-0.61	0.06	-10.23	0.00
β_2	-0.15	0.06	-2.42	0.02
β_3	-1.20	0.06	-20.09	0.00
β_4	-2.93	0.06	-46.22	0.00
β_5	-3.79	0.07	-51.61	0.00
β_6	-1.90	0.06	-32.99	0.00
β_7	-3.51	0.07	-49.22	0.00
β_8	-7.39	0.28	-26.61	0.00
IT_{12}	0.63	0.06	10.37	0.00
IT_{13}	-1.20	0.06	-21.33	0.00
IT_{14}	0.27	0.07	3.66	0.00
IT_{15}	0.21	0.08	2.53	0.01
IT_{16}	0.50	0.06	8.83	0.00
IT_{17}	-1.39	0.12	-11.56	0.00
IT_{18}	-1.69	0.36	-4.67	0.00
IT_{23}	-0.85	0.06	-13.54	0.00
IT_{24}	-1.16	0.08	-15.25	0.00
IT_{25}	-1.75	0.10	-16.76	0.00
IT_{26}	1.15	0.06	19.6	0.00
IT_{27}	-2.75	0.18	-15.45	0.00
IT_{28}	0.59	0.33	1.8	0.07
IT_{34}	1.18	0.07	17.11	0.00
IT_{35}	-0.60	0.13	-4.5	0.00
IT_{36}	0.40	0.05	7.38	0.00
IT_{37}	1.24	0.08	15.07	0.00
IT_{38}	5.39	0.28	19.28	0.00
IT_{45}	1.53	0.12	13.24	0.00
IT_{46}	1.01	0.06	15.97	0.00
IT_{47}	2.94	0.08	35.99	0.00
IT_{48}	3.36	0.34	9.93	0.00
IT_{56}	2.72	0.08	35.26	0.00
IT_{57}	-2.33	0.42	-5.61	0.00
IT_{58}	-4.28	0.65	-6.54	0.00
IT_{67}	-0.47	0.09	-5.19	0.00
IT_{68}	0.89	0.22	3.94	0.00
IT_{78}	-19.34	586.73	-0.03	0.97
IT_{123}	0.39	0.07	5.95	0.00
IT_{124}	-0.22	0.10	-2.18	0.03
IT_{125}	0.23	0.06	3.59	0.00
IT_{126}	-0.26	0.06	-4.36	0.00
IT_{128}	0.47	0.14	3.36	0.00

IT_{134}	0.69	0.09	7.99	0.00
IT_{137}	0.65	0.13	4.91	0.00
IT_{138}	1.13	0.34	3.29	0.00
IT_{145}	-0.64	0.14	-4.42	0.00
IT_{146}	-0.71	0.08	-8.38	0.00
IT_{147}	-0.47	0.15	-3.11	0.00
IT_{148}	-0.76	0.18	-4.32	0.00
IT_{156}	0.53	0.09	6.17	0.00
IT_{167}	-0.64	0.22	-2.91	0.00
IT_{168}	-1.32	0.77	-1.71	0.09
IT_{234}	1.66	0.08	20.17	0.00
IT_{235}	1.16	0.25	4.66	0.00
IT_{236}	-0.10	0.06	-1.66	0.10
IT_{237}	0.46	0.25	1.89	0.06
IT_{238}	1.20	0.33	3.64	0.00
IT_{246}	-0.11	0.07	-1.66	0.10
IT_{247}	1.07	0.25	4.28	0.00
IT_{248}	0.73	0.42	1.75	0.08
IT_{256}	0.81	0.10	7.95	0.00
IT_{267}	-0.72	0.17	-4.14	0.00
IT_{268}	-0.48	0.08	-5.83	0.00
IT_{345}	-0.80	0.24	-3.34	0.00
IT_{346}	-0.40	0.06	-6.32	0.00
IT_{347}	-1.50	0.10	-15.09	0.00
IT_{348}	-1.78	0.34	-5.21	0.00
IT_{356}	-1.21	0.17	-7.12	0.00
IT_{367}	1.62	0.10	16	0.00
IT_{368}	-0.70	0.22	-3.2	0.00
IT_{456}	-1.96	0.14	-13.9	0.00
IT_{457}	-1.24	0.68	-1.83	0.07
IT_{468}	-0.50	0.08	-6.56	0.00
IT_{1234}	-0.67	0.12	-5.53	0.00
IT_{1245}	0.37	0.20	1.83	0.07
IT_{1246}	0.24	0.11	2.19	0.03
IT_{1247}	0.90	0.24	3.71	0.00
IT_{1248}	0.66	0.19	3.42	0.00
IT_{1268}	-0.45	0.19	-2.32	0.02
IT_{1345}	0.42	0.24	1.77	0.08
IT_{1368}	1.34	0.75	1.78	0.08
IT_{1467}	0.88	0.26	3.38	0.00
IT_{1468}	0.73	0.14	5.12	0.00
IT_{2345}	-0.54	0.27	-1.99	0.05
IT_{2347}	-1.34	0.32	-4.19	0.00
IT_{2348}	-1.27	0.42	-3	0.00
IT_{2356}	-0.84	0.28	-3.04	0.00
IT_{2456}	0.75	0.17	4.33	0.00
IT_{3456}	1.14	0.29	3.91	0.00
Intercept	9.65	0.06	160.27	0.00