Method for Assessing the Consequences of Natural and Man-Made Emergencies (on the Example of the Siberian Federal District of Russia)

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Abstract. The paper presents a method to assess and forecast consequences of natural and man-made emergencies, based on regions of the Siberian Federal District of Russia. A single common measure for all emergencies can be found only in socio-economic consequences of emergencies — both natural and man-made accidents. This measure is the number of victims, as well as the amount of losses. The calculations are based on the factors that adjust the number of victims and losses from natural and man-made disasters to the population level and prices of 2000. The paper presents some statistics of emergency situations in the Siberian Federal District for 2000–2010. Based on the calculation results, forecast maps for damage caused by natural and man-made emergencies, as well as for total damage for 1960, 1990, 2010–2020, were created.

1. Introduction
Forecasting consequences of emergency situations, both natural and man-made ones, is an important scientific issue which is relevant to the safety of the anthroposphere. Hence, there is an urgent need to develop a methodological framework for integrated assessment of consequences caused by emergency situations of different origins. This assessment was performed on the basis of regions included in the Siberian Federal District of Russia. For a more complete understanding of the issue, the research technique is discussed below.

The importance of Siberian Federal District is reinforced by its special geopolitical position: the region is not only an integrating link between the Far Eastern economic region and the European part of the country, but also a “bridge” between foreign European countries and the Asia-Pacific region. A lot of academic specialists from different countries are learning emergencies [1, 2, 3, 5, 11, 12].

Natural disasters are the most unpredictable or leave out events. According to EMERCOM of Tomsk Region [7], more than 20% of all emergencies (natural, man-made and biosocial) are of natural origin, which indicates their frequency in this region.

2. Research Technique
A single common measure for all emergencies can be found only in socio-economic consequences of emergencies — both natural and man-made accidents. This measure is the number of victims, as well
as the amount of losses. However, when using these data, we have to take into account the fact that there were much fewer people on the Earth in the past, while the property was much cheaper than now. For example, in 1281, about 80 thousand people died in floods in Western Europe. Now, given the current population density, the number of victims would be much greater. We can assume that the number of victims and property damage remain proportional to the total population size. Then, using the available historical data on population sizes of regions in past times, we can calculate the adjustment factors and multiply the true number of victims by these factors in order to adjust it to the population size of 2000 [10].

Using the data on the population size for 1960–2010 (Table 1), the author calculated the adjustment factors for losses for all regions of the Siberian Federal District (Table 2).

Table 1. Population Sizes of Regions of the Siberian Federal District [6, 9].

| Region              | 1960   | 1970   | 1980   | 1990   | 2000   | 2010   |
|---------------------|--------|--------|--------|--------|--------|--------|
| Altai Republic      | 157.1  | 168.2  | 172    | 190.8  | 202.9  | 206.2  |
| Republic of Buryatia| 673.3  | 812.2  | 899.4  | 1,038.2| 981.2  | 972.7  |
| Tyva Republic       | 171.9  | 230.8  | 267.6  | 308.5  | 305.5  | 307.9  |
| Republic of Khakassia| 411    | 445.8  | 498.4  | 566.8  | 546.1  | 532.3  |
| Altai Territory     | 2,683.2| 2,670.2| 2,686.2| 2,631.3| 2,607.4| 2,419.4|
| Zabaykalsky Territory| 1,085.5| 1,210.6| 1,301  | 1,452.4| 1,227.5| 1,106.6|
| Krasnoyarsk Territory| 2,615.1| 2,961.9| 3,198.5| 3,038.6| 2,966.1| 2,828.2|
| Irkutsk Region      | 1,976.4| 2,313.4| 2,558  | 2,824.9| 2,581.7| 2,419.4|
| Kemerovo Region     | 2,786.9| 2,918.3| 2,958.4| 3,171.1| 2,899.1| 2,763.4|
| Novosibirsk Region  | 2,298.5| 2,505.2| 2,620.1| 2,778.7| 2,692.2| 2,656.9|
| Omsk Region         | 1,645  | 1,823.8| 1,956.8| 2,141.9| 2,079.2| 1,977.5|
| Tomsk Region        | 746.8  | 785.7  | 866.7  | 1,001.6| 1,046  | 1,045.5|
| **Total**           | 17,249.7| 18,846.1| 19,983.1| 21,144.8| 20,134.9| 19,254.3|

Table 2. The Factors that Adjust the Number of Victims and Losses from Natural and Man-Made Disasters to the Population Level and Prices of 2000.

| Region              | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |
|---------------------|------|------|------|------|------|------|
| Altai Republic      | 0.77 | 0.82 | 0.84 | 0.94 | 1.0  | 1.0  |
| Republic of Buryatia| 0.68 | 0.82 | 0.91 | 1.05 | 1.0  | 1.0  |
| Tyva Republic       | 0.56 | 0.75 | 0.87 | 1.01 | 1.0  | 1.0  |
| Republic of Khakassia| 0.75 | 0.81 | 0.91 | 1.03 | 1.0  | 1.0  |
| Altai Territory     | 1.02 | 1.02 | 1.03 | 1.01 | 1.0  | 1.0  |
| Zabaykalsky Territory| 0.88 | 0.98 | 1.05 | 1.18 | 1.0  | 1.0  |
| Krasnoyarsk Territory| 0.88 | 0.99 | 1.07 | 1.02 | 1.0  | 1.0  |
| Irkutsk Region      | 0.76 | 0.89 | 0.99 | 1.09 | 1.0  | 1.0  |
| Kemerovo Region     | 0.96 | 1.01 | 1.02 | 1.09 | 1.0  | 1.0  |
| Novosibirsk Region  | 0.85 | 0.93 | 0.97 | 1.03 | 1.0  | 1.0  |
| Omsk Region         | 0.79 | 0.87 | 0.94 | 1.03 | 1.0  | 1.0  |
| Tomsk Region        | 0.71 | 0.75 | 0.82 | 0.95 | 1.0  | 1.0  |
| **Total**           | 0.85 | 0.93 | 0.99 | 1.05 | 1.0  | 1.0  |

The average estimated property damage from man-made and natural emergencies was determined by the formula:

\[ Y_p = S\Delta(2010-2000), \]  

(1)

where \( Y_p \) is the average estimated property damage from man-made and natural emergencies;  
\( S \) are the average values of property damage from man-made and natural emergencies for 2000–2010;  
\( \Delta \) is the average property damage from man-made and natural emergencies per capita, rubles;  
\( N_{(2010-2000)} \) is the change in the population size of the region for 2000–2010.

Thus, the presented technique enables a full and comprehensive assessment of the damage from natural and man-made emergencies. A feature of this technique is the ability to calculate losses and the
number of victims for past periods, as well as the ability to forecast losses and victims for future periods.

Next, we consider the statistics of natural and man-made emergencies based on regions of the Siberian Federal District.

3. Statistics of Emergencies in Regions of the Siberian Federal District

Statistical data on natural and man-made emergencies in the Siberian Federal District was kindly provided by the Siberian Regional Center of the Ministry of Emergency Situations of Russia.

By processing the data from the Ministry of Emergency Situations, the author obtained the following figures: natural emergencies and man-made emergencies account for, respectively, 65% and 35% of the damage caused to economies of the Siberian Federal District.

Then, the author calculated the property damage in millions of rubles for each region included in the Siberian Federal District for 2001–2010 (Table 3).

| Region of the Siberian Federal District | Losses from emergencies, million rubles |
|----------------------------------------|----------------------------------------|
|                                        | Man-made | Natural | Total   |
| Altai Republic                         | 34.67    | 115.41  | 153.73  |
| Republic of Buryatia                   | 17.80    | 236.58  | 237.95  |
| Tyva Republic                          | 10.55    | 18.11   | 29.30   |
| Republic of Khakassia                  | 12.35    | 34.7    | 43.69   |
| Altai Territory                        | 284.14   | 259.67  | 513.81  |
| Zabaykalsky Territory                  | 38.16    | 7.08    | 43.09   |
| Krasnoyarsk Territory                  | 43.30    | 89.65   | 132.01  |
| Irkutsk Region                         | 19.29    | 2.65    | 21.94   |
| Kemerovo Region                        | 11.45    | 3.3     | 14.08   |
| Novosibirsk Region                     | 141.92   | 75.44   | 207.36  |
| Omsk Region                            | 10.23    | 175.66  | 185.89  |
| Tomsk Region                           | 55.62    | 371.1   | 426.72  |
| **Total**                              | **679.52**| **1,389.35**| **1,952.84**|

The analysis of Table 3 shows that the Tomsk Region ranks first in terms of the damage from natural emergencies. The Irkutsk Region ranks last. In terms of damage from man-made emergencies, the Altai Territory and the Omsk Region rank first and last, respectively. In terms of total damage, i.e., the damage caused by both natural and man-made emergencies, the Altai Territory clearly ranks first; the Kemerovo Region ranks last. Thus, the Kemerovo Region is the most prosperous region in terms of the damage caused to the regional economy.

Next, a forecast of consequences caused by natural and man-made emergencies in the Siberian Federal District is discussed.

4. A Forecast of Consequences Caused by Natural and Man-Made Emergencies in the Siberian Federal District

Using the adjustment factors to convert damages from natural and man-made emergencies (Table 2), we calculated the property damage for regions the Siberian Federal District for years 1960, 1970, 1980 and 1990, adjusted to the population level and prices of 2000 (Table 4).
Table 4. The Property Damage from Natural and Man-Made Emergencies in the Siberian Federal District, Adjusted to the Population Level and Prices of 2000, million rubles.

| Region of the Siberian Federal District | 1960 N | 1970 M | 1980 N | 1990 M |
|----------------------------------------|--------|--------|--------|--------|
| Altai Republic                          | 1.54   | 1.95   | 2.05   | 2.1    |
| Republic of Buryatia                    | 1.56   | 50.66  | 61.09  | 2.09   | 67.79  | 2.41   | 70.95  |
| Tyva Republic                           | 14.61  | 1.51   | 19.57  | 2.02   | 22.7   | 2.34   | 26.36  | 2.67   |
| Republic of Khakassia                   | 29.85  | 0.07   | 32.23  | 0.08   | 36.2   | 0.09   | 40.9   | 0.09   |
| Altai Republic                          | 18.56  | 84.86  | 18.56  | 84.86  | 18.38  | 82.37  |
| Republic of Buryatia                    | 617.05 | 35.2   | 687.17 | 39.2   | 736.26 | 42     | 827.4  | 33.89  |
| Tyva Republic                           | 1.49   | 21.91  | 1.68   | 24.65  | 1.81   | 26.64  | 1.73   | 24.41  |
| Republic of Khakassia                   | 237.5  | 9.57   | 278.12 | 11.21  | 309.3  | 12.47  | 340.6  | 11.55  |
| Altai Territory                         | 4.99   | 1.53   | 5.25   | 1.61   | 5.3    | 1.63   | 5.66   | 1.46   |
| Republic of Buryatia                    | 2.80   | 13.6   | 3.06   | 14.88  | 3.2    | 15.52  | 3.39   | 15.53  |
| Tyva Republic                           | 1.89   | 1.50   | 2.08   | 1.65   | 2.25   | 1.78   | 2.47   | 1.84   |
| Republic of Khakassia                   | 2.13   | 3.12   | 2.25   | 3.3    | 2.46   | 3.60   | 2.85   | 4.63   |
| Total                                  | 933.97 | 225.48 | 1,053.49 | 246.62 | 1,141.95 | 261.69 | 1,274.03 | 252.10 |

Note: N – natural emergencies; M – man-made emergencies.

By adding up the values of property damage caused by natural and man-made emergencies, we obtained the total property damage (Table 5).

Table 5. The Total Property Damage from Natural and Man-Made Emergencies in the Siberian Federal District, Adjusted to the Population Level and Prices of 2000, million rubles.

| Region of the Siberian Federal District | 1960 | 1970 | 1980 | 1990 |
|----------------------------------------|------|------|------|------|
| Altai Republic                         | 3.49 | 3.69 | 3.78 | 4.53 |
| Republic of Buryatia                   | 52.22| 62.97| 69.88| 73.36|
| Tyva Republic                          | 16.12| 21.59| 25.04| 29.03|
| Republic of Khakassia                  | 29.92| 32.31| 36.29| 40.99|
| Altai Territory                        | 103.42|103.42|104.39|100.75|
| Republic of Buryatia                   | 652.25|726.37|778.26|861.29|
| Tyva Republic                          | 23.4 | 26.33| 28.45| 26.14|
| Republic of Khakassia                  | 247.07|289.33|321.77|352.15|
| Altai Territory                        | 6.52 | 6.86 | 6.93 | 7.12 |
| Republic of Buryatia                   | 16.4 | 17.94| 18.72| 18.92|
| Tyva Republic                          | 3.39 | 3.73 | 4.03 | 4.31 |
| Republic of Khakassia                  | 5.25 | 5.55 | 6.06 | 7.48 |
| Total                                  | 1,159.45|1,300.11|1,403.64|1,526.13|

By adding up the values of forecast property damage from natural and man-made emergencies, we obtained the values of forecast total property damage (Table 6).
Table 6. Calculation of the Forecast Total Property Damage from Natural and Man-Made Emergencies in the Siberian Federal District, 2010–2020.

| Region of the Siberian Federal District | Total property damage, million rubles |
|----------------------------------------|--------------------------------------|
| Altai Republic                         | 153.73                               |
| Republic of Buryatia                   | 237.95                               |
| Tyva Republic                          | 29.30                                |
| Republic of Khakassia                  | 43.69                                |
| Altai Territory                        | 511.23                               |
| Zabaykalsky Territory                  | 43.09                                |
| Krasnoyarsk Territory                  | 122.01                               |
| Irkutsk Region                         | 20.85                                |
| Kemerovo Region                        | 14.30                                |
| Novosibirsk Region                     | 203.07                               |
| Omsk Region                            | 181.96                               |
| Tomsk Region                           | 378.09                               |
| Total                                  | 1,952.84                             |

We also calculated the property damage from natural and man-made emergencies for the period until 2030, 2040 and 2050, using the amount of damage for the period until 2020 as the basis. The calculations are based on the assumption that the amount of damage for the period until 2020 increases depending on the population growth or decline in the calculation period. The results are presented in Table 7.

Table 7. Average Property Damage from Natural and Man-Made Emergencies in the Siberian Federal District for 2010–2020, Adjusted to the Population Level and Prices of 2000, million rubles.

| Region of the Siberian Federal District | 2020 | 2030 | 2040 | 2050 |
|----------------------------------------|------|------|------|------|
|                                        | N    | M    | N    | M    | N    | M    | N    | M    |
| Altai Republic                         | 1.54 | 1.95 | 1.64 | 2.05 | 1.68 | 2.1  | 1.88 | 2.65 |
| Republic of Buryatia                   | 1.56 | 50.66| 1.88 | 61.09| 2.09 | 67.79| 2.41 | 70.95|
| Tyva Republic                          | 14.61| 1.51 | 19.57| 2.02 | 22.7 | 2.34 | 26.36| 2.67 |
| Republic of Khakassia                  | 29.85| 0.07 | 32.23| 0.08 | 36.2 | 0.09 | 40.9 | 0.09 |
| Altai Territory                        | 18.56| 84.86| 18.56| 84.86| 18.7 | 85.69| 18.38| 82.37|
| Zabaykalsky Territory                  | 617.05| 35.2 | 687.17| 39.2 | 736.26| 42  | 827.4| 33.89|
| Krasnoyarsk Territory                  | 1.49 | 21.91| 1.68 | 24.65| 1.81 | 26.64| 1.73 | 24.41|
| Irkutsk Region                         | 237.5| 9.57 | 278.12| 11.21| 309.3 | 12.47| 340.6| 11.55|
| Kemerovo Region                        | 4.99 | 1.53 | 5.25 | 1.61 | 5.3  | 1.63 | 5.66 | 1.46 |
| Novosibirsk Region                     | 2.80 | 13.6 | 3.06 | 14.88| 3.2  | 15.52| 3.39 | 15.53|
| Omsk Region                            | 1.89 | 1.50 | 2.08 | 1.65 | 2.25 | 1.78 | 2.47 | 1.84 |
| Tomsk Region                           | 2.13 | 3.12 | 2.25 | 3.3  | 2.46 | 3.60 | 2.85 | 4.63 |
| Total                                  | 933.97| 225.48| 1,053.49| 246.62| 1,141.95| 261.69| 1,274.03| 252.10|

Note: N – natural emergencies; M – man-made emergencies.

Thus, using the proposed technique, we calculated the damage from emergencies of different origins and made a forecast of possible damage in the future for a certain time frame.
5. Rankings of Regions of the Siberian Federal District in Terms of Property Damage from Emergencies of Different Origins

Table 8 ranks the regions of the Siberian Federal District in terms of property damage from emergencies of different origins.

**Table 8.** Rankings of Regions of the Siberian Federal District in Terms of Property Damage from Emergencies of Different Origins.

| Rating | Natural emergencies       | Man-made emergencies     | Total damage from emergencies of different origins |
|--------|---------------------------|--------------------------|----------------------------------------------------|
| 1      | Tomsk Region              | Altai Territory          | Altai Territory                                    |
| 2      | Altai Territory           | Novosibirsk Region      | Tomsk Region                                       |
| 3      | Republic of Buryatia      | Tomsk Region             | Republic of Buryatia                               |
| 4      | Omsk Region               | Krasnoyarsk Territory    | Novosibirsk Region                                |
| 5      | Altai Republic            | Zabaykalsky Territory    | Omsk Region                                        |
| 6      | Krasnoyarsk Territory     | Altai Republic           | Altai Republic                                     |
| 7      | Novosibirsk Region       | Irkutsk Region           | Krasnoyarsk Territory                              |
| 8      | Republic of Khakassia    | Republic of of Buryatia  | Republic of Khakassia                              |
| 9      | Tyva Republic             | Republic of Khakassia    | Zabaykalsky Territory                              |
| 10     | Zabaykalsky Territory     | Kemerovo Region          | Tyva Republic                                      |
| 11     | Kemerovo Region           | Tyva Republic            | Irkutsk Region                                     |
| 12     | Irkutsk Region            | Omsk Region              | Kemerovo Region                                    |

The rankings in terms of property damage from emergencies of different origins, presented in Table 9, show that the Tomsk Region ranks first in terms of damage from natural emergencies. The Irkutsk Region ranks last. In terms of damage from man-made emergencies, the Altai Territory and the Omsk Region rank first and last, respectively. In terms of total damage, i.e., the damage caused by both natural and man-made emergencies, the Altai Territory clearly ranks first; the Kemerovo Region ranks last. Thus, the Kemerovo Region is the most prosperous region in terms of the damage caused to the regional economy.

6. Conclusion

The key conclusions arising from the above discussion are summarized below:

1. The paper presents a technique to calculate losses from emergencies of different origins based on the factors that adjust the number of victims and losses from natural and man-made disasters to the population level and prices of 2000.

2. For the period under study, natural emergencies account for the bulk (65%) of the damage caused to economies of the Siberian Federal District. The contribution of man-made emergencies is 35%. Most of the damage from natural disasters is associated with hydrological hazards, such as flooding of settlements. Man-made emergencies, mainly car accidents, account for the bulk of deaths.

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