Economics of Security Working Paper Series

economics-of-security.eu

Alexander Ramseger, Martin B. Kalinowski, and Lucia Weiß

CBRN Threats and the Economic Analysis of Terrorism

February 2009

Economics of Security Working Paper 9

This publication is an output of the Network for the Economic Analysis of Terrorism, which is funded by the European Commission.

Network for the Economic Analysis of Terrorism
N E A T
www.economics-of-security.eu

Economics of Security is an initiative managed by DIW Berlin

Economics of Security Working Paper Series

The Economics of Security Working Paper Series combines outputs of European Security Economics (EUSECON), a research project supported by the European Commission's Seventh Framework Programme, with outputs of the Network for the Economic Analysis of Terrorism (NEAT), which is funded by the European Commission's Directorate General for Justice, Freedom, and Security. Papers not funded by EUSECON or by NEAT can still be submitted for inclusion in this Working Paper Series.

Correct citation: Ramseger, A., Kalinowski, M. B. and Weiß, L. (2009). "CBRN Threats and the Economic Analysis of Terrorism", prepared for the Network for the Economic Analysis of Terrorism (NEAT). Economics of Security Working Paper 9, Berlin: Economics of Security.

First published in 2009

ISSN: 1868-0488

For further information, please contact:

Economics of Security, c/o Department of International Economics, German Institute for Economic Research (DIW Berlin), Mohrenstr. 58, 10117 Berlin, Germany.

Tel: +49 (0)30 89 789-277

Email: neat@diw.de

Website: www.economics-of-security.eu

Economics of Security is an initiative managed by DIW Berlin

CARL FRIEDRICH VON WEIZSÄCKER CENTRE FOR SCIENCE AND PEACE RESEARCH

CBRN Threats and the Economic Analysis of Terrorism

Alexander Ramseger
Martin B. Kalinowski
Lucia Weiß

21. November 2008

Universität Hamburg

Executive summary

This paper was produced under contract from the German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung, DIW) in Berlin, on behalf of the Network for the Economic Analysis of Terrorism (NEAT). It was written by members of the Carl Friedrich von Weizsäcker Centre for Science and Peace Research (ZNF) in Hamburg.

The aim of this paper is to investigate the economic aspects of CBRN threats. For this purpose, the extent to which this topic is reflected in freely-accessible academic literature and the costs associated with such threats will be assessed. Furthermore, it is to be determined which industries have a particular interest in security against such CBRN threats.

The publicly accessible literature regarding CBRN terrorism is limited and does not provide a homogeneous database; therefore, the information found varies widely. This is due to the fact that completely different assumptions are used in terms of methodology and standards applied. In addition, the results differ both in the dimensions of the incidents under consideration and in the comprehensiveness of the areas of economic impact for which are accounted. This applies not only to studies of hypothetical scenarios, but also to historic events and easily accountable units, like the number of casualties. For the Bhopal accident, the number of casualties is estimated, by different studies, to be between 2,500 and 17,500. In case of Chernobyl, the expected number of early cancer fatalities ranges from 1,200 to 75,000.

Nuclear threat scenarios are separated here from the area of the other three hazardous substances. Although huge mortality figures (736,000 to 8,660,000 in Ramana (1999)) or large economic losses (DM 63 – 93 b per year *(€ 182 – 271 b per year)* in Reich (1971)) are estimated, this involves war scenarios, which are not easily compared with acts of terrorism.

In the course of this study, it became clear that studies in connection with biological incidents carry the largest monetary figures. For example, in the Katarisk study, the assumed possible direct damage from a biological disaster with CHF 2,010 million/year is 10 to 20 times greater than the expected amount of loss for both chemical and radiological incidents. In the cases of indirect damage, biological incidents take first place in McKibbin (2006), with an estimate of 4.4 trillion USD (11% of the global GDP) for pandemic influenza. Likewise in the area of prevention and protection, there is not only the most data, but also the highest amounts for biological threats.

The financial resources that are used for counter-measures against terrorist attacks also exhibit huge differences. In this area there was often an overlap with goals not related to the prevention of or the protection against CBRN terror, in particular regarding an increase of general security in the chemical industry. For some activities, CBRN terror is only a minor aspect, for instance the major objective of the destruction of chemical weapons is disarmament, but at the same time this investment prevents access of chemical weapons to terrorists.

In general, the total impact costs of large incidents are very high, and are much higher that that of counter-measures. For biological threats, the indirect economic impact is assessed to be in the range of several billion to tens of billions of US dollars. The countermeasure cost range is much lower, ranging from hundreds of millions to about 10 billion USD. Taking the bio defence programmes alone, a few hundred thousand to tens of millions are spent by European countries for a reference year, while the USA invests about 200 million euros.

Regarding the investigation of self-interest in security, direct questioning proved to be of limited use, as was expected. Further investigations of the security requirements of industries were carried out indirectly via third parties, who work within the context of risk prevention. It was found that primarily industries with a high symbolic value, as well as those representing

numerous potentially threatened people, regard themselves at risk of attack and thus exhibit a security interest.

When consolidating the findings of various approaches (direct interviews, third parties, literature review), it can be assessed that a strong interest in robust security regarding CBRN terror acts can be found in the following branches as defined by the United Nations Statistics Division: agriculture, certain industries (chemistry, shipping), electricity, gas and water supply, transport, storage and communications, financial intermediation, public administration and defence, and extra-territorial organizations and bodies. Further, some interest can be expected in the fishing industry, hotels and restaurants, real estate, renting and business activities, other community, social and personal service activities, possibly in wholesale and retail trade, and also in the health sector.

Though it appears that branches that are most endangered by possible terrorist threats with CBRN substances indicate the private sector's self interest in strong security, this study was not able to provide solid proof thereof. In regards to this finding, the unavailability of insurance against CBRN damages from terrorist acts is unfortunate.

Recommendations

- The costs of countermeasures against CBRN threats by terrorists appear very high when compared to available financial resources, and, therefore, it is advisable that each measure proposed to enhance the security against CBRN threats by terrorists be carefully examined in regards to its need, efficiency and effectiveness.
- The literature review suggests that, in general, the investment in countermeasures appears to pay off, since the possible economic damage of a CBRN attack would be higher than the investments in countermeasures. One should not, however, jump to premature conclusions regarding the cost-effectiveness of countermeasures.
- The high damage costs are caused by singular events for which no probability can be determined. Hence, a sound cost-benefit analysis based on a risk assessment is often impossible. Therefore, decisions on countermeasures should be taken by looking into alternatives, including low-budget options. The investments should also be considered with the opportunity cost of the community in mind. Even without a CBRN attack, countermeasures may pay off, as long as they are also addressing the possibility of other incidents, such as natural disasters.
- The efficiency of countermeasures should be carefully considered; in particular, the possibility for terrorists to circumvent a preventive measure. In addition, the terror threat should be addressed from an analysis of its roots and possible ways and means to diffuse the motivations of terrorists.
- Every cost-benefit analysis done on CBRN countermeasures should clearly define its scope, the share of costs, the distribution of avoidable damage costs (internal as well as external) and possible synergies with other objectives, like protection against accidents.

Branches that are most endangered by possible terrorist threats should receive adequate support. This could either be financial aid from the state or the availability of insurance against CBRN damages resulting from terrorist acts.

Table of contents

Index of tables

I. Introduction

The first part of this report assesses the costs in relation to CBRN threats in a quantitative way. A system of matrices is used, in which costs are related to the different types of CBRN incidents, e.g. chemical, biological, radiological and nuclear events. Further, a differentiation is made between costs caused by the impact of CBRN incidents (1.1) and costs of countermeasures (1.2).

After explaining this system, certain remarks on the currency translation and the inflation adjustment are made. The first chapter proceeds with a short overview of the economic impact of estimated casualties resulting from CBRN incidents and finishes with some qualitative considerations.

The report continues with the presentation of the research results. In the second chapter, the different groups of CBRN incidents are examined using historical examples to illustrate chemical (2.1), biological (2.2), radiological (2.3) and nuclear incidents (2.4).
After summing up the main results for each of the four sections – chemical, biological, radiological and nuclear incidents – the fifth chapter concludes with a final statement on this part. This final statement evaluates weaknesses and strengths with regard to the presented results, taking the working process into account.

The second part should answer the question: Which sectors and companies have an interest in high security? To find this out, representatives from relevant industries have been interviewed regarding their financial expenditure on CBRN security[1], while third parties acting in the field of CBRN security were asked about their clients in various industries, specifically in reference to their clients' interests in security.

The qualitative assessment of interest in robust security is based on interviews with representatives from several industries. The industries were selected in accordance with the United Nations Statistics Division and evaluated with regard to the probability of them being attacked, as well as the resulting interest in security. Since information on such sensitive precautions is treated in a confidential manner (as is naturally the case in the area of risk aversion and protection against terrorist attacks), a detailed statement on the available security concepts or the financial resources employed to this end could not be expected. This was confirmed by interviews with representatives of the respective industries; either a statement on the topic was immediately rejected or, after expression of a sincere interest in security precautions, any further statement was refused for security reasons.

1 The questionnaire can be found in Appendix A.

1. Categorisation of CBRN threats

In order to investigate the possible economic impacts of CBRN attacks, it is essential to discuss the differences between the substances used. Furthermore, it is necessary to clearly distinguish between CBRN attacks, CBRN-related accidents, and criminal acts.

The following definitions are used:

CBRN threat is the most comprehensive term, describing a probable threat emerging from chemical, biological, radiological or nuclear substances. Moreover it includes dangerous situations, which can arise intentionally (criminal acts, terror acts, acts of war) as well as unintentionally (accidents, natural catastrophes).

CBRN incident refers to an incident that has already taken place, with damage caused by hazardous CBRN material.

CBRN attack is also either a subcategory of CBRN threats or CBRN incidents depending on whether it is a hypothetical threat or an actual incident. One must further distinguish within these acts between terrorist attacks or attacks during a time of war.

Possible appearances of CBRN attacks include[2]:

Chemical attacks
• Nerve agents (SARIN[3], VX[4])
• Blood agents (hydrogen cyanide)
• Choking agent (chlorine)
• Blistering agents (mustard gas)

Biological attacks
• Poison (ricin, botulinum toxin)
• Viruses (smallpox, viral hemorrhagic fevers, flu)
• Bacteria (anthrax)
• Plagues (black plague, tularemia)

Radiological attacks
• Radiological dispersal device (dirty bomb)
• The spread of radioactive contaminants without a bomb or device
• Poisoning of food or beverages with radioactive isotopes

Nuclear terrorism
• Attack on a nuclear facility
• Explosion of a self constructed primitive nuclear bomb
• Stealing a bomb and extortion

---

2 Enders (2006), Institute of Medicine (2002), and White (2003)
3 Schrader, Ambros, Rüdiger, Linde, chemical nerve agent
4 An extremely toxic substance whose only application is in chemical warfare as a nerve agent

II. Quantitative Assessments of economic impacts of CBRN threats

1. Methodology

The first step in the assessment of economic impact is to break down CBRN threats into major types[5], and the second step is to make a list of relevant costs. To relate these costs to the CBRN threats, a system of matrices is used in order to ensure the completeness of the investigations.

1.1. Costs caused by the impact of CBRN incidents

In this area there are three main cost categories related to first-response measures, recovery, reconstruction and restoration, as well as indirect damage. These are described in the following paragraphs and a detailed breakdown by cost items is presented in Table 1.

First response
Costs incurred by first response measures include: rescuing and evacuating people involved in an attack or accident, preventing the spread of dangerous material, cordoning off the contaminated areas, and immediate decontamination.
Due to the fact that costs for first response measures usually are negligibly small, it is not expected to find much information about it in literature on CBRN incidents.

Recovery, reconstruction, restoration
Medium-term costs have to be taken into consideration in this section. Costs are incurred by measures such as health care for victims, pensions for the disabled, forensic tests on the deceased, as well as by funerals and life insurance claims paid out.
Moreover, clean up measures have to be carried out; these include the complete reconstruction of destroyed buildings and infrastructure, resettlement measures, and decontamination, e.g. waste management of dangerous substances and the removal of any involved material, living or dead.

Indirect damage costs
Above all, the loss of earnings as a consequence of a CBRN attack has to be considered. In this regard there are several factors to consider: loss of earnings could be caused by a loss of consumer confidence, which could have an impact on the tourism sector for example. Generally speaking, the state of emergency and the resulting deadlock of a whole national economy affect earnings. Even a temporary infrastructure breakdown would affect the economy. Moreover, employees would not be able to work full-time due to injuries.
In the long run, there would be certain effects in the macroeconomic context, such as loss of investor confidence or ensuing costs for injured employees.

[5] See categorisation of CBRN threats.

Table 1: Breakdown of costs caused by CBRN incidents

	Chemical	Biological	Radiological	Nuclear
First response	• rescue of injured and threatened people • evacuation • registration of contamination • blocking the spread of dangerous CBRN materials • immediate decontamination • measures to cordon off the contaminated area			
Recovery, reconstruction, restoration	• health care for injured people • costs for the deceased (medical forensics, funerals, life insurances) • pensions, etc for disabled people • cleaning up measures and thorough decontamination • reconstruction of buildings • resettlement and relocation • restoration of infrastructure: transport system, public services (water supply, electricity, telephone network) • gathering of infected animals • clearance of contaminated cadavers and plants • waste management (most importantly disposal of CBRN substances)			
Indirect damage costs	• loss of earnings caused by loss of consumer confidence • loss of earnings caused by (preventive) culling • loss of earnings caused by decline in tourism • loss of earnings resulting from injuries/sicknesses or death of employees • loss of earnings because of state of emergency (regional and international) • economic impact of temporary infrastructure breakdown: transportation system, public services (water supply, electricity, telephone network)			
Macroeconomic costs	• consequential costs from loss of income (multiplier effects) • loss of investor confidence/propensity to save			

1.2. Costs for countermeasures against CBRN incidents

Regarding countermeasures against CBRN incidents, one can distinguish between costs for prevention of CBRN incidents and costs for protection against them. Both are described in the following paragraphs and a detailed breakdown of individual countermeasures is given in Table 2.

Prevention
Research facilities and programmes must observe current developments in the field of CBRN-related dangers. In order to anticipate an attack with CBRN material, certain monitoring networks have to be established. The main factor in this field is preparedness concerning risk assessment as well as training of security personnel, medical staff, certain specialists, and the threatened population. Moreover, warehouses containing CBRN materials must be kept under constant surveillance using portal monitors, security barriers, video observation, and, more generally, import and export controls.

Protection
In this context, protection actually means providing security for critical infrastructure and the general public with the help of access controls, portal monitors and security barriers in general. It is necessary to establish governmental and private organizations, which control certain security standards in order to assure a sufficient level of security.

Preparedness
This term describes costs spent to minimise direct consequences of CBRN incidents, for example capability of first response measures or costs for training of qualified persons and threatened citizens.

Table 2: Breakdown of cost items for Counter-Measures against CBRN incidents

<table>
<tr><th></th><th>Chemical</th><th>Biological</th><th>Radiological</th><th>Nuclear</th></tr>
<tr><td>Prevention</td><td colspan="4">Stockpiling of antibiotics, diagnostics, vaccines and, management thereof

Establishment and management of monitoring networks

Establishment of new research facilities and programmes

Biosecurity review

Preparedness
risk assessment
situation awareness
security personnel
training of qualified persons and threatened populations
governmental authorities and private organisations for situation observation and assessment
Physical protection for the warehouses containing CBRN materials:
portal monitors
import and export control
security barriers, fences, video observation</td></tr>
<tr><td>Protection</td><td colspan="4">Protection for the critical infrastructures and the general public against threats arising from CBRN terrorism/criminality/accidents:
access control
portal monitors
protection against intrusion: security barriers, fences, video observation
Human security
risk assessment
situation awareness
governmental authorities and private organizations for situation
portal monitors
import and export control
security barriers, fences, video observation
access control
protection against intrusion: security barriers, fences, video observation
security personnel
training of qualified staff and endangered populations
governmental authorities and private organizations for the control of certain security standards</td></tr>
<tr><td>Preparedness</td><td colspan="4">training of qualified persons and endangered populations
governmental authorities and private organizations for situation observation
first response capabilities</td></tr>
</table>

1.3. Qualitative remarks on cost figures[6]

Foreign currency translation and inflation adjustment

All costs are given in Euros (exchange rate 2006). They have been converted after inflation adjustment by dividing by the GDP deflator (base year 2006).

The amounts indicated in Euros (2006) are respectively added in italics behind the original values in the tables.

Cross-counting cost comparison with GDP fraction

In order to facilitate an evaluation of the costs, they are also given as a percentage of nominal GDP, which are noted in red letters following the values of € 2006 in scientific notification ($nx10^m$).

1.4. Economic impact of casualties

To estimate the economic impact of CBRN-related events, one could take into account other affects, such as the number of casualties. The amount and type of damage can be translated into a financial loss. With regard to cost figures, it is important to distinguish clearly between the economic value assumed for a lost life and compensation demands for a lost life.

This paper also considers the expected number of dead and injured people resulting from a CBRN incident. The conversion of human life into economic form depends on an individual's "worth" in terms of his or her earnings, time spent working, and money invested in education.

According to a representative from an international insurance company[7], insurance companies have experienced that legal claims in respect of loss of human life are settled quite differently in different regions of the world. Publicly available loss statistics indicate that typically, settlements of fatality claims in the USA are often in the order of some million euros.

The costs for the lifelong support of a young invalid are much higher than the economic loss caused by his death.

The average economic values given represent a rough approach and can only be used to approximately estimate the economic impact of a CBRN event.

---

6 See International Monetary Fund, Organisation for Economic Co-operation and Development and German Federal Bank

7 American International Group, American insurance corporation

2. Selected Historical Cases

To provide a robust forecast, it would be necessary to refer back to numerous real terror cases. This is not possible, because there are only very few historic examples of chemical and biological terror acts, and none for radiological and nuclear ones. Therefore, studies that deal with the economic consequences of historic CBRN incidents are used.

Examples used for CBRN incidents are:

Chemical incident: 1995 attack by Aum sect in the Tokyo subway system

Biological incident: Anthrax attacks of 2001 in the USA

Radiological incident: Palomares accident of 1966 in Spain

Nuclear incident: Atomic bombs dropped on Hiroshima and Nagasaki, Japan, in 1945

Only one historical example for every CBRN incident is presented.

No historical examples are given for radiological and nuclear terror attacks, therefore, historical examples have been chosen that can be compared to terror acts in their consequences. It is very difficult to estimate the possible range of impact of a CBRN attack due to the complexity of the system used in the attack, as well as the dimensions of the attack itself.
Palomares was chosen because of the contamination of agricultural land. The amount of contamination is comparable to that of a terror act. For a nuclear attack, studies treating the atomic bomb attacks on Hiroshima and Nagasaki are used. In comparison to chemical, biological and radiological terror attacks, a nuclear terror attack is the least probable.

2.1. SARIN attack of 1995 in Tokyo

In the early hours of 20 March 1995, five members of the Japanese Aum sect deposited plastic bags, each wrapped in newspaper, on five commuter trains of three Tokyo subway lines. Inside the plastic bags was the neurotoxic substance SARIN. Immediately after the offenders left the trains, they cut the plastic bags with umbrellas to set the liquid SARIN free. The emitted fumes propagated into the subway trains as well as roughly 15 subway stations. Altogether 12 people died in the direct aftermath of the attack. More than 1,000 people were injured. The reason for the relatively small number of casualties is the low quality of the SARIN, the ineffective employment of the SARIN, and the effective reaction of Japanese security forces. [8]

Table 3: SARIN attack of 1995 in Tokyo: injured and killed people

Total number of injured people	> 1,000
Total number of killed people	12

[8] Pangi (2002)

2.2. Anthrax attack of 2001 in the USA

In 2001 several attacks with anthrax were carried out in the USA. In each attack, anthrax spores were sent in granular form by post to broadcasting stations and newspapers. Furthermore, some letters were also sent to US senators. Several workers at the postal facilities that processed the letters fell ill with pulmonary anthrax.

Altogether 22 people were infected with either cutaneous or pulmonary anthrax, and five of those infected with the pulmonary form died[9]. Beyond the toll in human lives, the attacks also carried significant costs in terms of disruption and decontamination. Selected congressional office buildings were closed for periods of up to several months. More than a year later, postal facilities in Washington, DC, New Jersey, and Connecticut, and the AMI[10] building in Florida remained closed. The costs of decontaminating congressional offices and postal facilities will easily run into the tens of millions, if not higher. In addition to these costs stemming from direct remediation efforts, there are additional (not tabulated) economic costs resulting from the disruption of the postal system.

The economic impacts are outlined below in a chronology of the anthrax attacks[11]:

15 January 2002: US postal and law enforcement officials announce that the reward for information on the perpetrator(s) of the anthrax attacks will be increased to 2m USD.

22 January 2002: Official announcement of the increase in the reward for information. In addition, postal and law enforcement officials announce that they will send out 500,000 flyers targeting central New Jersey and Bucks County, PA in a search of additional information. The Hart Office Building officially reopens after 96 days of quarantine and decontamination. The EPA[12] estimates that it has spent13.3m USD on clean-up operations, and expects the total cost to rise to 20m USD.

26 March 2002: Postal officials estimate that it will cost 35m USD to clean both the Brentwood and Hamilton (NJ) postal facilities.

26 July 2002: Postal service officials hold a press conference to announce that a test of decontamination techniques at the Brentwood facility will be conducted on 29 July. Postal officials also estimate that it will cost approximately 22m USD to decontaminate the facility.

30 July 2002: Postal service officials in New Jersey announce that the Trenton Processing and Distribution Center in Hamilton will be reopened in the spring following a 20 million dollar decontamination and renovation process.

9 Hicklin (2002)
10 American Media Inc.
11 National Defense University (2002).
12 Environmental Protection Agency

Table 4: Economic impact of anthrax attack of 2001 in the USA

Preventive costs	2m USD *(€ 1.78m)* to get information on the perpetrator(s) 1.97×10^{-05}
Costs for decontamination	90.3m USD *(€ 80.46m)* 8.92×10^{-04}
Total number of killed people	5
Total number of injured people	22

2.3. Palomares accident of 1966 in Spain

On 17 January 1966, an accident involving US American nuclear weapons occurred on the south-west coast of Spain near the town of Palomares. A B52-bomber collided with a KC-135 aircraft while refueling at a height of 9,000 metres, with both aircrafts crashing on Spanish terrain. Three of the four hydrogen bombs fell on the inhabited area of Palomares, the fourth fell into the sea. The safety precautions taken had helped in avoiding a thermonuclear explosion. However, the high-explosive burster charges detonated. Because of this explosion, radioactive material (plutonium) was dispersed across several hectares of agricultural land. Within three months more than 1,500 tons of radioactive contaminated soil was disposed of.

Table 5: Palomares accident of 1966 in Spain. Economic impact

Recovery, reconstruction, restoration	Total costs for aircraft SALVOPS MED[13]: 10.23m USD *(24.99 m €)*.6.1×10^{-04} [14] Clean-up costs per hectare after Palomares accident: 33.6m USD *(43.78 m €)* 7.53×10^{-04}. [15]

[13] Aircraft Salvage Operations Mediterranean, actions that resulted in the at-sea search, identification and recovery of one of the nuclear weapons.
[14] Field Command (1975)
[15] Baes (1986)

2.4. Nuclear bomb attacks on Hiroshima and Nagasaki in 1945

Only two examples in history exist to examine the impact of nuclear weapons on densely populated areas: the atomic bomb attacks on Hiroshima (6.8.1945, with an equivalent 16 kilotons of TNT) and Nagasaki (9.8.1945, with an equivalent 21 kilotons of TNT). In this section, the number of dead and injured people resulting from the attacks is presented. No studies on the economic impact of the attacks have been found. Unfortunately, those parameters that have been taken into consideration vary substantially. The duration of the aftermath effects and the area that was affected are estimated. Furthermore, the causes of death or injury have not been specified. Normally, there are three direct causes of death and injury by a nuclear attack: heat wave, blast, and radiation. Of these effects, heat wave and blast are more substantial in their impact on innate objects and humans than radiation. Beside these three effects, the radioactive fallout causes cases of cancer and contamination of the surrounding area. In order to indicate the inaccuracy of information on the given numbers of deaths caused by cancer, such victims are classified under "death by non-specified cancer". Inaccurate numbers of deaths and injured people are classified under "total sum of injured people" and "total sum of killed people".

Table 6: Attacks with nuclear bombs on Japan: dead and injured people

People killed directly	45,000 in Hiroshima[16] 31,000 in Nagasaki[16]
Number of people who died in the aftermath of the attacks (cause of death not specified)	15,000 in the first three weeks in Hiroshima[16] 60,000 in the first year in Hiroshima[16] 32,000 in the first three weeks in Nagasaki[16] 17,000 in the first year in Nagasaki[16]
Death by leukaemia in the aftermath of the attacks	13 observed up to 1950 in Hiroshima[17] 10 observed up to 1950 in Nagasaki[17]
Death by non-specified cancer in the aftermath of the attacks	31,881 between 1950 and 1997 for both cities[18]
Total number of injured people	72,200 in Hiroshima[19] 25,000 in Nagasaki[19] 72,000 injured and survived in Hiroshima[20] 25,000 injured and survived in Nagasaki[20]
Total number of killed people	140,000 in Hiroshima[21] 70,000 in Nagasaki [21] 64,400 in Hiroshima[19] 39,000 in Nagasaki [19] 136,000 in Hiroshima[20] 64,000 in Nagasaki[20]

16 Cosset (1997)
17 Folley (1952)
18 Kodama (2007)
19 Pastore (1987)
20 Vogel (2007),
21 Kataoka (2008)

3. Literature review

The aim of the literature review was to find studies on CBRN attacks and to analyse their economic findings. As very few cases of CBRN terror attacks exist, the studies presented refer to CBRN incidents such as accidents and war scenarios.

In relation to chapter 2, in which some historical examples are considered, this chapter also evaluates studies dealing with the possible impacts of CBRN attacks.
This review is separated into two parts: the first part looks at nuclear threats and the second part at chemical, biological and radiological threats. The review is based mainly on publicly accessible literature.

First, two studies which look only at the effects of nuclear weapons used in acts of war are introduced. There is hardly any literature on the use of nuclear weapons for terrorist acts, which may be due to the difficulty of implementation that such an act requires. On the other hand, there are many studies dealing with chemical, biological and radiological terror acts. Furthermore, an additional chapter looks at chemical, biological or radiological threats together. This chapter is mainly based on a rather general Swiss study entitled "Katarisk".

3.1. Literature base on CBRN threats

The investigated studies differ in terms of their chosen economic contexts. One group looks at historical cases and evaluates their economic impact, while another estimates possible scenarios and their probable financial impact. A third group looks at financial efforts to prevent chemical, biological or radiological attacks or to minimise their consequences. Studies from the first and second group naturally focus only on costs that occur in the aftermath of such an incident. The parameters used in these studies vary, as do the number of examined or estimated damaging events. Few studies look at the impacts of all three hazardous substances mentioned on a global scale, at long-term and short-term effects, or at macroeconomic and microeconomic effects. Most studies only look at the impact of an attack with one substance on a finite region. An example for a study treating the impact of all three substances is the "Katarisk" study. See the summaries of these studies in the following sections: 3.2, 3.3, 3.4 deal with those studies that are substance-specific and 3.5 presents studies that cover all three CBR substances without making explicit distinction. The estimated costs are presented in appendix B.

With regard to nuclear threats, two studies are used for this report: "Bombing Bombay"[22] and "Die wirtschaftlichen Schäden eines atomaren Krieges in der Bundesrepublik Deutschland"[23] ("The economic damages of an atomic war in the Federal Republic of Germany"). Both studies are discussed in chapter 4.5, and the predicted economic impacts are shown in the matrices in appendix B.

Below are the summaries of the studies examined, divided according to the hazardous substance with which they deal. First, studies concerning terror acts are described, then those which deal with CBRN threats are looked at on a more general level. In both cases, the

[22] Ramana (1999)
[23] Reich (1971)

consequences are comparable. As chemical, biological and radiological threats are sometimes discussed together in one study, there is a separate chapter for such reports.
All expected economic impacts are listed in the matrices in appendix B.

3.2. Chemical threats

In regards to chemical terrorism, two studies are evaluated in this literature review. Schneidmiller (2005) discusses the increase in security by the US chemical industry. He directly connects these efforts to the attack on the World Trade Center in 2001. A study that treats the consequences of a chemical attack is Pangi (2002) (see also section 2.1). Pangi describes the attack on the subway system in Tokyo by the Aum sect and specifies the number of killed and injured people.

The Bhopal incident is looked at in detail because although it was not even caused by terrorist action, there is a large amount of literature on the incident. See the estimated values in appendix C. Though the Bhopal accident was a historical occurrence, and thus a well-defined event, estimates of the number killed are range between 2,500 and 17,500.

Chemical threat is an area in which high costs are incurred. In order for the USA to ensure first response to such a threat, annual figures show that between 10 and 15 billion dollars are used. The Katarisk study covers the subject of directly estimated costs. The damage and loss figures estimated here are in the same order of magnitude as those assumed for potential radiological scenarios (several hundred million dollars). The indirect costs, on the other hand, turn out considerably higher, and various studies estimate them in billions (varying from several tens of billions to several hundred billion dollars). The costs needed for prevention are always in the region of several billion dollars. The costs needed for protection, however, are again in the region of the tens of billions of dollars, with the highest figure of 72 billion dollars.

3.3. Biological threats

Most studies were found in the field of biological attacks, some of which concern the financial expenditure on security surrounding biological attacks, e.g. Malakoff (2002), Trust for Americas Health (2007), Government Accounting Office (2003), Gursky (2004), Haase (2005), Carafano (2003), Gottron (2003), National Defense University (2003), Moodie (2003), National Defense University (2002), Davis (2002) and Armstrong (2004). All of these studies treat preventive costs, e.g. for vaccines, hospitals, biosensor networks, clinical research and food safety initiatives. A very detailed and well-researched study concerning preventive costs is Hunger (2005). It looks at the financial expenditure of various countries on bio-defense programmes. The estimated amounts are presented separately in Table 18 in Appendix B: Cost Matrices.In contrast to these studies, Wein (2005) looks at the possible impacts of a biological terror attack. He examines the number of casualties caused by a botulinumtoxin attack on the milk industry. A study regarding the real impact of a biological incident is, for example, Keogh-Brown (2008), who evaluates the financial impact by the SARS[24] epidemic in 2003.

By far the greatest number of studies found deal with costs relating to biological threats. Figures for first response (some tens of billions of dollars) and for indirect costs (up to several hundred billion dollars) are in the same region as those for the chemical threats. Sums for

[24] Severe acute respiratory syndrome

direct costs of recovery and reconstruction, however, are more than ten times larger than those for chemical and radiological hazards (in the billions). Prevention and protection costs are likewise in the same region as those for chemical threats, i.e. several billion dollars for prevention, and tens of billions for protection.

3.4. Radiological threats

Two studies concerning radiological attacks are used. Royal Society (2008) looks at the amount spent on the prevention and detection of, and response to, the illicit trafficking of radiological material that can be used for radiological dispersal devices.
In his paper, Zimmermann (2004) discusses the possible financial damage of an attack with a radiological dispersal device (abbreviated as RDD). He assumes that the impact of such a RDD in New York would be at least as severe as the terrorist attacks on the World Trade Center in Manhattan in 2001.

A study investigating a number of fictional radiological incidents and the effects associated with them is that of Brown (2006). This study starts by describing the potential attack scenarios and ends by estimating the numbers of dead and injured resulting from them. Brown then discusses the costs that would be necessary to establish a nationwide detection network.

Furthermore, two studies on the Goiania accident are presented. In de Freitas (2001) and in Natarajan (1998) the numbers of killed and injured people in Brazilian slums contaminated by ^{137}Cs in 1987 are given.

As is for the Bhopal accident, many sources of information are available for the Chernobyl accident. For further details see Appendix D: The Chernobyl accident.

First response in regards to radiological threats has not been taken into consideration until now. Costs for recovery vary across an enormous spectrum and are estimated to be anywhere from several hundred million dollars (Katarisk 2003) to several trillion dollars (Brown 2006).

Costs for prevention of radiological attacks, at several hundred million dollars, are almost always less than the costs of prevention of chemical and biological incidents, which are estimated in the billions. The cost of protection from chemical and biological hazards is estimated to be in the tens of billions of dollars.

3.5. Chemical, biological and radiological threats

The "Katarisk" study by the Swiss "Bundesamt für Bevölkerungsschutz"[25] of 2003 considers the potential damage caused by environmental catastrophes, technological and social incidents. It provides extensive data concerning chemical, biological and radiological threats, and in terms of possible impacts, the basic costs can be transferred to the context of chemical, biological and radiological threats related to terrorism.

First, the study analyses the potential risk of certain scenarios. Using data from past events, it develops representative scenarios, describes the expected frequency and the expected financial impact. Five factors are considered: the number of injured people and casualties, the number of evacuated people, the number of people who need the state's support as a consequence of the incidence, the area of land damaged, and the costs for rebuilding measures. The different scenarios are evaluated in terms of monetary units so that they can be matched. In this context, the Katarisk study distinguishes between certain categories: category one describes events of daily life, while category five sums up the worst-case scenario. The estimated costs are all chosen from category five due to the fact that the expected CBRN impact will cause a worst-case scenario.

In addition, three more studies dealing with chemical, biological and radiological attacks have been used: Dixon (2007) estimates the expected total financial loss in a large metropolitan area on the US Atlantic coast for an anthrax, a radiological and a SARIN attack. In order to compare Dixon (2007) to Katarisk (2003) it is necessary to gross up the expected financial impact by multiplying by a percentage of GDP.

Chalecki (2001) and Shea (2004) present the real financial efforts by the US government to protect against CBR attacks (Shea only metions chemical and biological terrorism) and to reduce an attack's effectiveness.

The studies show that recovery and reconstruction after a biological incident tend to be the most costly, costing billions of dollars rather than hundreds of millions. Indirect costs for all three types of threats, however, amount to the same amount (several hundred million up into the hundred billions).For prevention and protection, the respective costs for all three hazardous materials are estimated in the same general region of several tens of billions of dollars. The economic aspects and expected financial impacts are shown in the matrices in appendix B.

---

25 Swiss Federal Department of Defence, Civil Protection and Sport http://www.vbs.admin.ch/internet/vbs/en/home.html

3.6. Nuclear threats

One of the latest current studies regarding the theoretical impact of an attack with a nuclear weapon is “Bombing Bombay” by M.V. Ramana. As a result of India’s and Pakistan’s nuclear tests in May 1998 and the conflict between these two countries, this topic gained importance. The report describes the direct effects of a nuclear detonation over the Indian city of Bombay. Bombay presents a typical target of a nuclear attack in a war. With a population of about ten million, Bombay is one of the biggest Indian cities and is India’s largest financial and industrial centre. Furthermore, Bombay has a big naval and commercial port. Ramana calculates the number of casualties following the detonation of a nuclear weapon in terms of people killed directly by:

1. thermal radiation and resulting large-scale firestorms
2. shock waves and accompanying high-speed winds
3. prompt radiation

His estimates of the number of casualties do not regard long-term effects, such as cancer or genetic mutations. These long-term effects would, as Ramana stresses, lead to thousands of casualties. Ramana estimates the number of deaths resulting from an attack with a 15-TNT-kiloton equivalent bomb (similar to the bombs dropped on Hiroshima and Nagasaki). For this attack, he assumes ideal conditions, like a clear day and an explosion height of 600 metres. He also estimates the death toll for a 150-TNT-kilotons equivalent bomb (like modern hydrogen bombs).

If terrorists were to detonate a bomb on the ground, the effects of a heat wave would be slightly reduced and the local radioactive fallout would be enhanced.[26]

Table 7: Total sum of killed people in “Bombing Bombay“

Total sum of killed people	• 160,000 to 866,000 in case of 15 TNT kilotons • 736,000 to 8,660,000 in case of 150 TNT kilotons

A further study that treats the possible amount of casualties in a nuclear attack is “Mathematische Analyse der Wirkungen von Kernwaffenexplosionen in der BRD”[27]. This study is part of a compilation of several studies, analyzing the consequences of a nuclear war in the Federal Republic of Germany between 1960 and 1970[28].This study calculates the impact of a nuclear weapon with a 20 Mt TNT equivalent on the city of Hamburg. The number of casualties of such an attack is estimated to be 1,270,000, while the number of injured at 463,000.

Another study treating the effects of nuclear weapons especially on economic effects is: “Die wirtschaftlichen Schäden eines atomaren Krieges in der Bundesrepublik Deutschland und ihre Folgen“[29]. Likewise from the same collection as the Sonntag study. The author examines the possible costs in three different economic fields:

- destruction of production facilities (which in the matrix is listed under “Recovery, reconstruction, restoration”)

[26] Glasstone (1964)
[27] Sonntag (1971)
[28] von Weizsäcker (1971)
[29] Reich (1971)

- destruction of the means of existence (which in the matrix is listed under "Indirect damage costs")
- breakdown of organisation (direct and indirect costs)

The economic impacts on these fields are examined in nine different war scenarios. These war scenarios differ in regard to the number of nuclear weapons used and the affected areas. Every war scenario depicts the actual status immediately after the weapon exertion and neglects dynamic processes. The assumed effects of the nuclear bombs are blast, heat wave, and fallout. The economic calculations are based on the population and the industrial circumstances of 1961.

For the first example, the author considers the number of destroyed industrial facilities. Furthermore he estimates the proportionality of industrial productiveness of the number of employed people in these industrial facilities. To calculate the exact outage of employed people, he takes towns and administrative districts as the smallest population unit. The effects of a nuclear weapon exertion are estimated according to these units. In contrast to the first estimation, the second concerns the essential production capabilities to ensure the survival of the population[30]. For this estimation the author considers the percentage of minimal industrial resources related to the production. They equal around 80% of the real given industrial facilities. For the third point, which is handled in a qualitative mode, no financial results have been calculated.

The main difference compared to "Bombing Bombay" is the higher number of nuclear bombs used in the scenario. Reich constructs a typical scenario of the cold war period, presuming 20-30 nuclear weapons (equivalent to 20 Mt TNT) dropped on German industrial regions. This is a realistic scenario for a war, but not for a terrorist act. In a terrorist attack, the use of one nuclear bomb at most is probable. It is not possible to compare the scenarios drawn by Ramana and Reich for several reasons. Ramana concentrates on a possible attack targeting a single city using a nuclear weapon, similar to that used on Hiroshima, and estimates the number of people killed. In contrast, Reich looks at the monetary impact on industrial areas caused by the usage of about 20-30 hydrogen bombs.

Table 8: Total direct costs in Reich (1971)

Recovery, reconstruction, restoration	(63 – 93 b Deutsche Mark per year *(182. – 271 b € per year)* (8.24 – 12.23)

While a terrorist attack using nuclear weapons is not highly probable, the scenario Reich creates is not very probable at all. However, the strength of Reich's study lies in the extent of his analysis of the possible consequences of a nuclear attack. The extent of the damages caused is not proportional to the number of weapons used. Therefore it is not possible to break down and transfer Reich's estimates into the framework of another attack using a bomb with less explosive force, such as described by Ramana.

Nevertheless a standardisation of the effects (on linear assumptions) described in Reich (1971) is possible. There are two possibilities for this: on the one hand, it is possible to determine an upper threshold by dividing by the number of nuclear weapons used, and on the other hand a lower threshold, by scaling down the number of nuclear weapons (Reich assumes hydrogen bombs, Ramana bombs of the Hiroshima type).

[30] The minimal production of comestibles is stated with 2,000 cal/person/day

Upper standardisation threshold: the scenario described by Reich involves the use of 20 to 30 nuclear weapons; if we divide his estimated figures of 182 – 271 billion euros by 25 (mean value of assumed bombs), the result is 7.28 – 10.84 billion euros.

Lower standardisation threshold: Reich assumes the effect of several 20 Mt bombs. For standardisation to the same number of bombs of the Hiroshima type (15 kt), a division is made by the ratio of the two figures (1,333.3). The values standardised to bombs of the Hiroshima type are 140m to 200m euros.

The values given as upper and lower thresholds can also be scaled down to one single bomb of the Hiroshima type. Damage would then be estimated between 5.6 and 8.1 million euros.[31] When considering the potential for damage of such a bomb in a present-day urbanized setting, this figure seems quite low. It indicates a lack of available data in order to produce a more plausible figure.

[31] This is a very rough calculation of the expected economic damage. Furthermore, two points have to be mentioned to assess these calculations in an adequate way. At first, Reich estimates only the direct damage concerning destroyed buildings, infrastructure, industry facilities, etc. No following economic effects caused by breakdown of infrastructure or loss of production are respected. He secondly did not regard psychological effects that can lead to economic effects or numbers of casualties.

5. Final statement on quantitative assessments

As explained above, it is rather difficult to compare all these studies on CBRN attacks. Because of the small number of historic terror cases, it is also necessary to look at CBRN accidents.

Without a larger number of cases to evaluate, it is very difficult to estimate the possible economic impacts, even without differentiating between incidents caused deliberately (mainly terror acts) and fortuitous events like accidents. At any rate, the consequences would not be the same in the majority of cases. Therefore the expected possible economic impact diverges greatly.

Remarks on studies regarding potential impacts of CBRN attacks

The studies considering potential scenarios vary in terms of extensiveness (e.g. type and number of weapons used, concerned area, geographical characteristics) and the economic consequences analysed (macro- and microeconomic, direct and indirect costs, number of casualties). The studies are shown in a diagram below, with the comprehensiveness of regarded economic impact on the horizontal axis and the dimension of the attack on the vertical axis.

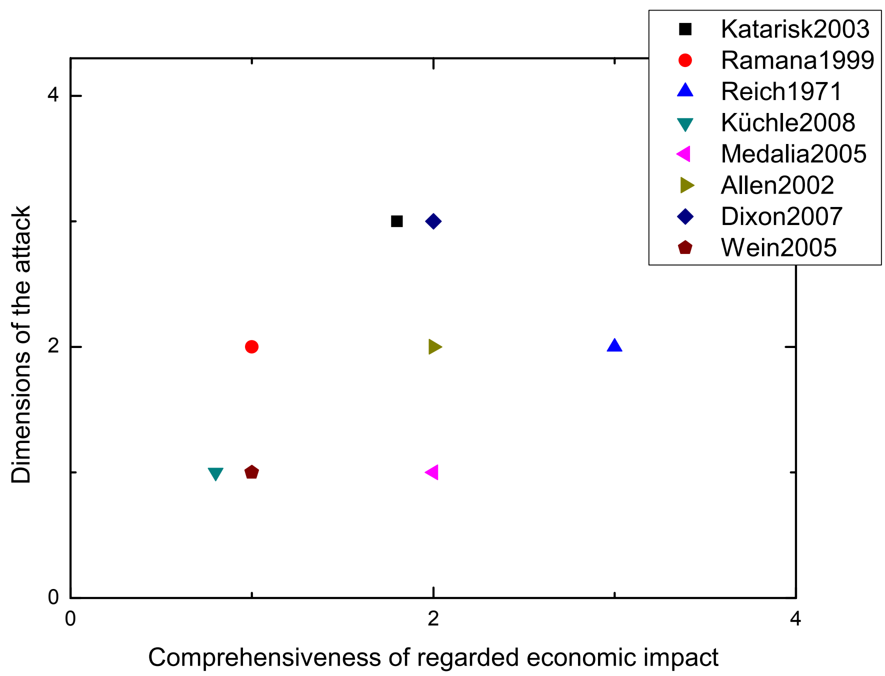

Figure 1: Dimensions of the attack vs. the comprehensiveness of regarded economic impact. All studies dealing with possible scenarios are included.

For studies on real attacks, this classification is not sensible, because only attacks using one substance for a certain target and the economic consequences they caused were analysed.

Even the financial expenditures to prevent such attacks or to minimise their consequences vary widely. It was also determined that the terms used in the literature such as "indirect costs" or "prevention costs" were employed in a very general manner and in fact used in a different manner at times. This makes it even more difficult to compare the amounts found with regard to these keywords.

The information on costs differs in the various studies to a large degree. The figures chosen are presented in the following table. They cover broad economic aspects and are explained in more detail in the following paragraph. See also Appendix B: Cost Matrices for a short description of the studies selected.

Table 9: Costs caused by the impact of chemical, biological and radiological threats

	Chemical	Biological	Radiological
First response		Between 10 and 30 billion USD per year. *(8.48b to 25.44b €/year)* (8.56×10^{-02} – 2.57×10^{01})[32]	
Recovery, reconstruction, restoration	CHF 125m/year *(87.39m €/year)* 2.86×10^{-02}/year without risk aversion CHF 190m/year *(132.83m €/year)* with risk aversion [33]	CHF 2,010m/year *(1405.05m €/year)* 4.59×10^{-01}/year without risk aversion CHF 7,751m /year *(5418.92m €/year)* with risk aversion[34]	CHF 118m/year *(82.49m €/year)* 2.70×10^{-02}/year without risk aversion CHF 1,546m /year *(1080.85m €/year)* with risk aversion[35]
Indirect damage costs		58b USD *(46.19b €)* 4.4×10^{-01} [36]	

[32] Shea (2004)
[33] Katarisk (2003)
[34] Schneidmiller (2005)
[35] Schneidmiller (2005)
[36] Küchle (2008)

Table 10: Costs for Counter-Measures against chemical, biological and radiological threats

	Chemical	Biological	Radiological
Prevention	> 2b USD *(1.64b €)* $1.82x10^{-01}$ [37]	1.748b USD *(1.53b €)* $1.59x10^{-02}$ [38]	200m euros [39] $1.04x10^{-03}$
Protection		1.555b USD *(1.41b €)* $1.54x10^{-02}$ [40]	
Preparedness		Between 10 and 30 billions USD *(8.48b to 25.44b €/year)* ($8.56x10^{-02}$ – $2.57x10^{01}$)[41]	

Remarks on the figures of table 10 and 11:

Because of different estimates in the used studies, short explanations are present below.

The figures for the indirect damage costs and the costs for protection are related to general CBR scenarios. A categorisation of the various effects of single substances has not been made within these studies. Only in the field of costs for first-response measures associated with a radiological attack was no information found.

Since the data presented refers to several countries, it is hardly possible to draw a comparison. The costs for first response measures are related to the USA. They represent expenditures not only calculated, but also actually spent. In contrast, the amount of money given in the table for probable damages is based on a national catastrophe scenario for Switzerland.

Moreover, the indirect damage costs are also based on a model calculation. It works out the probable costs for the whole US economy as a result of an attack on a large US port using a chemical, biological or radiological weapon. For the field of prevention, separate information is available for all three sectors. The US chemical industry, for example, has spent more than two billion dollars since the 9/11 attacks in order to improve its security. With regard to biological terror threats, the USA has various security programmes, which have been running over several years. These programmes include clinical research, and research regarding therapeutics, drugs and vaccines, and construction and renovation of biosafety laboratories.

The European Union has invested more than 200 million euros in detection of and response to illicit trafficking of radiological material in order to prevent radiological attacks. This value is clearly greater compared to the values employed by European countries within the scope of security against biological attacks (compare with the values in Appendix B in Hunger (2005). If one compares the values indicated in Brown (2006) for the introduction of a blanket detection system (> 500m USD), then it can be seen that the amounts are on the same scale.

37 Schneidmiller (2005)
38 Moodie (2003)
39 Royal Society (2008)
40 Chalecki (2001)
41 Shea (2004)

The efforts to equip American harbours with so-called ASP[42] monitors have been postponed in order to save on costs for the time being. The costs of development and procurement of the ASP monitors require about 1.2 billion USD.[43]

The table refers to the cumulative expenditure of the US government in the fiscal year 2001 for security for chemical, biological and radiological terrorist attacks.

42 Advanced Spectroscopic Portal
43 Government Accountability Office (2006)

III. Allocation of expenses for CBRN countermeasures on various stake holders in different sectors

1. Methodology

This part of the report assesses which sectors and companies have an interest in security against CBRN attacks and which do not. For this reason, industries and sectors are classified according to their interest in robust security. Interviews with representatives of selected companies or organisations were conducted to find out whether there is interest at all and how far the management is engaged in promoting it.

To compile a register of possible industries and sectors interested in robust security, it will be helpful to obtain market estimates from companies that manufacture devices for protection against CBRN hazardous substances. This will provide an overview of possible customers, for example public authorities requiring security, but also private institutions. This can be done in two ways: First, one can determine the level of interest by asking industry representatives directly. Second, it is possible to determine the level of interest by speaking to third parties[44].

Examples of third parties:

Suppliers and distributors of technical equipment or facilities used to prevent such attacks as well as to minimise the consequences in the aftermath. For example, in the field of prevention there are producers of detection or control systems. Furthermore, there are companies that produce technical equipment to deal with the aftermath of a CBRN attack, for example protective clothing. Most of this technical equipment is not specific to terrorist attacks. Conclusions can only be drawn regarding measures against CBRN threats in general.

The questions posed to industry representatives aim at obtaining concrete information on the security precautions as well as the associated costs. However, for security reasons, precise specification could not be expected, but only information on whether there is any interest at all in security against CBRN attacks and whether precautions have been taken for protection.

To assess the different players in the above-mentioned industries and sectors with regard to CBRN threats, three factors must first be considered:

a) What does the financial loss incur, i.e. the issue of internalities and externalities?

In economics, an externality is an impact on any party not directly involved in an economic process. The impact of a CBRN terror attack is to be seen as a reason for an unintentional economic process (in the perception of the directly affected party). An externality occurs when an economic activity causes external costs[45].
Inevitable to the issue of internalities and externalities is to what extent the consequences of this terror act affect other parties. The second part of this deliberation leads to the question: Other than the direct target of the attack, who is damaged? Naturally, companies will insure themselves against damages that affect them directly.

---

44 The name of the respective staff member was omitted if requested by the respective third parties.
45 For example Brück (2008)

b) Why me? (Game Theory)

For companies that are affected especially by intangible assets, the incentive to insure themselves is eminently high. This is because of the high loss in confidence in industries such as transportation and travel companies or food-store and food supply chains.

However, the incentive for a company to insure itself is diminished if it does not expect to be affected directly. It hopes that other companies will provide insurance or at least financial means to minimise the impacts of a CBRN attack. Such decisions are apparently rational but occur in restricted conditions (theory of Collective Action[46]) and result in cases of underinsurance. The economic theory of Collective Action is concerned with ensuring the Common Good through the collaboration of two or more individuals and the impact of externalities on group behaviour. Olson's theory explores market failures where individual consumer rationality and firms' profit-seeking do not lead to efficient provision of the Common Good, i.e. where another level of provision would provide a higher utility combined with lower costs.

c) Public Interest or Common Good

One can explain the same phenomenon in another way: the absence of attacks is a Common Good, the appearance of attacks is a Common Bad.

Under certain conditions private players will produce a Common Good, which normally has to be done by the state. In some cases, only the state has the financial assets to react to a CBRN attack and to minimise the impacts.

The main characteristic of a Common Good as well as a Common Bad is that they affect everyone, and nobody can extract themselves from the effects. Furthermore, the damage of one affected player does not decrease the amount of damage on another affected player.

From these deliberations the following hypotheses are deduced to divide market participants and industries into three categories, with regard to their interest in insurance against CBRN attacks. These categories differ in the degree of probability of being potentially direct or indirect targets for CBRN attacks:

a) Category 1: Market participants and industries that are directly and indirectly affected by CBRN attacks will insure themselves and spend money on minimising the impacts of a CBRN attack in an adequate way.

b) Category 2: Market participants and industries that are directly affected by CBRN attacks will underinsure themselves and spend money on minimising the impacts of a CBRN attack in a minimal way.

c) Category 3: Market participants and industries that are indirectly affected by CBRN attacks will insure themselves and spend money on minimising the impacts of a CBRN attack in an insufficient way.

Examples for the three categories:

Category 1: airports, railroad companies, food-store or food-supply chains, sports stadiums

Category 2: suppliers (water, energy)

Category 3: industrial plants, for example car manufacturers

---

46 Olson (1971)

It is difficult to distinguish between market participants and industries that are affected by a CBRN attack either in a direct or in an indirect way. For example, any industrial producer could be a possible direct target of an attack. In this case, this industrial producer would fall into category 2. However, the same producer could belong to category 3 if, for example, main logistical nodal points are damaged or supply chains are broken. In this case there would be only indirect damage.

The issues of self-interest in robust security are the same for all three categories. The main difference between these categories is the extent of the insurance and the additional financial expenditure (for technical, personnel or logistical arrangements).

In addition to the surveys, the sponsors of the specified costs were searched for in the related literature. Thus a determination of self-interest was also possible in part.

2. Branches

2.1. Branches according to the United Nations Statistics Division

In order to make a distinction between individual branches, the Unite Nations Statistics Division[47], which defines the following 17 industries, was relied upon:

- Agriculture
- Fishing
- Mining and quarrying
- Manufacturing
- Electricity, gas and water supply
- Construction
- Wholesale and retail trade
- Hotels and restaurants
- Transport and communications
- Financial intermediation
- Real estate, renting and business activities
- Public administration and defence; compulsory social security
- Education
- Health and social work
- Other community, social and personal activities
- Private households with employed people
- Extra-territorial organisations and bodies

In addition to this list, the self-interest in robust security for broadcasting corporations and newspaper publishing companies should also be estimated.

2.2. Categorisation of branches in terms of their interest in robust security against CBRN threats

To determine their interest in robust security, representatives from branches with a high-risk potential in CBRN attacks are considered. Different industries are not equally attractive as targets. For the evaluation, certain branches with an assumed high attack potential were chosen.

[47] http://unstats.un.org/unsd/default.htm, see UNO (2006)

2.3. Selected branches

Agriculture: This sector has to be considered as extremely sensitive. An attack in the agriculture sector could tie up large parts of the food-processing industry. Thereby the livelihood of the majority of the population could be endangered. Furthermore, the damage caused by a loss of confidence is immense and can affect agricultural undertakings, as well as the food processing industry. For loss in confidence see e.g. the immense impacts of BSE[48], which was of course not an attack, but a biological incident.
Hypothesis: Representatives of this branch fall into category 1.

Production: Industrial plants and production facilities are good examples of locations where direct damages can occur. Through the disruption of important logistical nodal points, externalities could occur.
Hypothesis: Representatives of this branch fall into category 2 or 3.

Energy and water supply: Like the agricultural sector, the field of energy and water supply is also very sensitive. In contrast to the agricultural sector, the effects of a possible loss of confidence are not that drastic.
Hypothesis: Representatives of these branches fall into category 1.

Transport and communications: The effect of attacks on these branches will primarily affect externalities in other branches.
Hypothesis: Representatives of these branches fall into category 2.

Credit and insurance companies: Representing the western economic system, financial centres such as the stock market in Frankfurt are places with great symbolic value.
Hypothesis: Representatives of these branches fall into category 2 or 3.

Public administration and defence: One has to distinguish between attacks on e.g. administrative buildings that could indirectly impact other industries and representative attacks.
Hypothesis: A categorisation is rather difficult, for example military facilities abroad fall in category 1.

Health system: highly attractive target because of great direct impact by a CBRN attack
Hypothesis: Representatives of this branch fall into category 1.

[48] Bovine spongiform encephalopathy

3. Market enquiries

3.1. Questionnaire

To gain an overview of the efforts made in the field of CBRN-related security measures, each representative was given a questionnaire[49] to answer. The first question is whether the organisation is highly endangered by CBRN attacks or not. The second question is whether there are security undertakings over and above the statutory security regulations and if so, what these measures are. The representatives answered these questions with regard to direct and indirect consequences of CBRN attacks. Since, as mentioned above, it could not be assumed that more precise data would be provided on the respective security precautions, the questionnaire documents the sensitivity of the questions posed.

Since presentation of the questionnaire was thus only used as an indicator of general interest, expert groups having more concrete estimates on the security requirements and any implemented precautions were also surveyed.

The questionnaire was sent per Mail after contacting the representatives via e-mail or phone.

3.2. Expert groups

Additionally, appraisements of expert groups in the field of CBRN security should help address the question of whether there is self-interest in robust security in some industries or not. Most importantly are measures taken that exceed the statutory regulations.

3.2.1. Insurance companies

One can assume that the level of insurance against direct or indirect effects of a CBRN attack is related to self-interest in CBRN security. Therefore, insurance companies are questioned regarding their allocation of customers in the field of CBRN incidents. The expenditures for insurance against CBRN attacks involve minimisation of the impact costs.

It is fundamental to distinguish between two kinds of insurance:

1. insurance of property
2. casualty insurance

The German[50] insurance law does not honour claims against third parties in cases of so-called “Acts of God”, such as a terror attacks. Therefore no casualty insurance exists for victims of terrorism. In contrast, the possibility of property insurance in cases of an “Act of God” exists. The only German insurance company that offers insurance against terror acts is the Extremus AG in Cologne. The results of this interview with a representative of the Extremus AG are presented in chapter 4.

[49] The questionnaire can be found in Appendix A

[50] Only the legal situation in Germany was taken into consideration since the surveys involve German industry representatives.

3.2.2. Security agencies and control agencies

In Germany there is a fairly large number of agencies and institutions that deal with national security. Four representatives (three security agencies and one control agency) were asked to give an estimation of the likelihood of a CBRN attack and their interest in robust security. The results are presented in chapter 4.

As explained above, the self-interest in robust security can be estimated in the financial expenditure exceeding the statutory regulations. These optional as well as the statutory security arrangements (technical and logistical) are controlled by independent organisations, such as the TÜV[51].

3.2.3. Producers of security equipment and safety advisers

In the field of security, there are producers of technical security equipment e.g. detection systems or protection clothing. Moreover, security consultant companies provide advice to clients regarding the necessity of CBRN security measures. Within the scope of the investigations, the manufacturer of detectors for locating radioactive substances (Thermo Fisher AG) and a company working in the area of security consulting (vdlconsult) were also surveyed.
Countermeasures are involved in the case of the costs incurred through the employment of producers of security equipment and safety advisers.

3.2.4. Selected branches representatives

In order to evaluate self-interest in security with regard to CBRN attacks, representatives from different industries were interviewed. The degree of probability of being targeted by a CBRN attack was the main criteria used to evaluate the relevant industries.

The interviews were conducted with the help of a standardised questionnaire, which is attached in Appendix A: Questionnaire.

The qualitative assessment of interest in robust security is based on interviews with representatives from several industries. Adapted from the classification of industries according to the United Nations Statistics Division, which lists 18 industries, contact was taken up in eleven representative industries, out of which altogether 19 representatives were questioned. While seven did not react at all, six confirmed an interest in CBRN-related security, declining further explanations for safety reasons. Five participants were not able to provide information in time. A surveyed representative (from the university hospital) did not regard himself as a possible target of an attack.

See table 13 for the representatives asked.

[51] Technischer Überwachungs-Verein

4. Enquiry results

This chapter presents the interview results.

Insurance companies

The Extremus AG in Cologne provides insurance policies against terrorist attacks[52], but CBRN attacks are categorically not covered [53]. Nevertheless, interest in this field exists. According to a representative of the Extremus AG, there are three main industries frequently enquiring after such an insurance offer:

- hotels
- chemical industry
- real estate

Table 11: Self-interest in robust CBRN security, appraisal by Extremus AG

Branch	Is there an interest in insurance with regard to CBRN-attacks?
Agriculture	Not specified
Fishing	Not specified
Mining and quarrying	Not specified
Manufacturing	Yes (especially chemical industry)
Electricity, gas and water supply	Not specified
Construction	Not specified
Wholesale and retail trade	Not specified
Hotels and restaurants	Yes (especially hotels)
Transport, storage and communications	Not specified
Financial intermediation	Not specified
Real estate, rental and business activities	Yes
Public administration and defence; compulsory social security	Not specified
Education	Not specified
Health and social work	Not specified
Other community, social and personal service activities	Not specified
Private households with employed persons	Not specified
Extra-territorial organisations and bodies	Not specified
Broadcasting stations, newspapers	Not specified

[52] The Extremus AG covers compensation demands up to 10 billion euros per year for risks with a total sum insured exceeding 25 million euros. The Extremus AG itself compensates amounts up to 2 billion euros, the remainder (at most 8 billion euros) is paid by the government. This agreement is valid until 31 December 2009. http://www.extremus.de/unternehmen_geschichte.phtml

[53] Extremus 2008

Security agencies and control agencies

The following responses were received from three institutions working in this area[54]:

- Behörde für Inneres der Stadt Hamburg (BfI[55]): The BfI is responsible for any security concerns of the city of Hamburg. This includes the hazard of CBRN attacks. A representative from the department for Disaster Control at the BfI, and a member of the Hamburg fire brigade were contacted but refused to make a statement.

- Bundesanstalt Technisches Hilfswerk (THW[56]): The THW is a federal agency and subordinate to the Ministry of the Interior. It has functions in the field of disaster control, especially in averting CBRN-related danger. For this reason, special CBRN task forces are available. A member of the CBRN defence team (Länderverband Bremen/Niedersachsen) explained that there are no variations in the safety concepts in the industries involved in an attack. Consequently, the THW is unable to make an appraisal of CBRN endangerment.

- Bundesamt für Strahlenschutz BfS[57]: The BfS has its headquarters in Salzgitter and is the federal agency responsible for radiation protection. Our request to speak to an expert was denied for safety reasons.

54 Another institution did not respond at all.
55 Hamburg Office of the Interior
56 German Federal Agency for Technical Relief
57 German Federal Office for Radiation Protection

Producers of safety features and equipments

In the field of preventive measures against CBRN substances, detectors to investigate such material are widely used. The Thermo Fisher AG produces detectors for radioactive material. Their client list reveals that mainly the steel industry, companies that deal with old industrial material, the waste recycling industry, as well as nuclear power plants use this technical device[58]. An interest in security can be concluded, but realistically it is accidents rather than acts of terror that are predominantly assumed.

Furthermore, the Thermo Fisher AG sells security products in order to anticipate the emergence of any dangerous situations. For example, portal monitors are used at airports or to check containers in order to detect illegally transported radioactive substances,[59] which may involve terror activities. In this regard, the monitors constitute a preventive measure.

Consulting in Safety

Apart from the demand for technical security support, industries also require security consulting. Mr Jürgen K. von der Lippe is the Executive Director of vdlconsult, a German company which advises companies on security questions. He considers the following economic sectors to be most endangered by CBRN attacks: all buildings with a high symbolic value, public places such as sports stadiums, centres of global finance and economy, and industrial facilities[60].

An interest in security is related to the possibility of being a target of such an attack. In addition to symbolic and political factors, the number of people that could potentially be killed or injured by a CBRN attack is also an important consideration. Models that could predict the possibility of an attack have to take into account political situations, social environment, security arrangements and the number of reachable possible casualties[61].

---

58 Thermo (2008)
59 For example Nürbchen (2003) and Thermo (2007)
60 von der Lippe (2005)
61 Such models are described for example in Kowalski (2003) or Arup (2002)

The table below shows Mr von der Lippe's evaluation of various industries' self-interest in security.

Table 12: Self-interest in robust CBRN security, appraisal by vdlconsult

Branch	There is a self-interest in robust CBRN-security
Agriculture	Yes
Fishing	Yes
Mining and quarrying	Not specified
Manufacturing	Yes
Electricity, gas and water supply	Yes
Construction	Not specified
Wholesale and retail trade	Not specified
Hotels and restaurants	Not specified
Transport, storage and communications	Yes
Financial intermediation	Yes
Real estate, rental and business activities	Not specified
Public administration and defence; compulsory social security	Yes
Education	Not specified
Health and social work	Not specified
Other community, social and personal service activities	Yes
Private households with employed persons	Not specified
Extra-territorial organisations and bodies	Yes
Broadcasting stations, newspapers	Not specified

Selected branches representatives

As was to be expected, representatives of industries considered to be highly threatened by CBRN threats – especially attacks – were not keen to respond to related questions. The selection of candidates would ideally have been based on appraisals by third parties, such as insurance companies and general security agencies (e.g. the German TÜV). However, in view of the expected limited response, representatives were selected at random.

The results of these enquiries are shown in table 14.

Table 13: Enquiry results

Branch	Representative	Self-interest in robust security against CBRN attacks
Agriculture	Large German dairy	Yes, anonymously mentioned in this report
Fishing	No investigation	
Mining and quarrying	No investigation	
Manufacturing	BASF[62]	No answer
Electricity, gas and water supply	1. Nuclear Power Plant in Brunsbüttel by E.ON AG[63] 2. RWE[64]	1. No result[65] 2. No result
Construction	No investigation	
Wholesale and retail trade	EDEKA Group[66]	No answer
Hotels and restaurants	DEHOGA[67]	No answer
Transport, storage and communications	1. Deutsche Bahn AG 2. HVV[68] 3. Vodafone[69]	1. Yes arrangements not specified 2.Yes, arrangements not specified 3. No result
Financial intermediation	The Hamburg Exchange	No answer
Real estate, rental and business activities	No investigation	
Public administration and defence; compulsory social security	1. Office of the Interior of Hanseatic City Hamburg 2. German Customs Office in Hamburg 3. Bundeswehr Command and staff college	1.Yes, but arrangements are in general the same for other kinds of threats 2.Yes, arrangements not specified 3. No answer
Education	No investigation	
Health and social work	University Medical Centre Hamburg-Eppendorf	Do not assess themselves as a possible target
Other community, social and personal service activities	1. HSH Nordbank Arena[70] 2. Color Line Arena[71]	1. No answer 2. No result
Private households with	No investigation	

62 Badische Anilin & Soda Fabrik, large German chemical company

63 Large German energy providing company

64 Rheinisch-Westfälisches Elektrizitätswerk, German electric power and natural gas public utility company

65 This column distinguishes between "No result" and "No answer". "No result" means that the contact to the representatives was made, but did not lead to a result. "No answer" means the absence of any reaction by the representative

66 Large German supermarket corporation

67 Deutscher Hotel und Gaststättenverband, largest German association for hotels and restaurants

68 Hamburger Verkehrsverbund. Hamburg public transport company

69 German mobile network operator

70 Hamburg Schleswig Holsteinisch Nordbank, sports stadium in Hamburg

71 Arena in Hamburg, used for ice hockey but also for larger events like concerts

employed persons		
Extra-territorial organisations and bodies	US Consulate in Germany	Yes, arrangements not specified
Broadcasting stations, newspapers	1. Large German publishing company 2. ARD[72]	1. They don't want to be mentioned in relation to CBRN threats 2. No answer

Three main problems arose in the course of these enquiries:

1. Many representatives did not want be mentioned within the context of a paper dealing with CBRN-related terrorism. Detailed statements were refused.
2. If there was interest in security issues related to CBRN attacks, specific comments were not given for safety reasons, and the information provided was strictly confidential.
3. The majority of the questioned representatives interested in CBRN-related security did not categorise measures taken against chemical, biological, radiological and nuclear threats.

[72] Arbeitsgemeinschaft der öffentlich-rechtlichen Rundfunkanstalten der Bundesrepublik Deutschland, Consortium of public-law broadcasting institutions of Germany

5. Final statement on cost allocation for CBRN Counter-Measures

The intended aim of this market enquiry was to examine certain parties' self-interest in robust security against CBRN attacks and to test the hypothesised categorisation explained in chapter 2.3.

Only a few rather general appraisals from third parties could be acquired. A few of the experts we approached in various institutions did not consider themselves accountable for security, or were not allowed to give any information as they were subject to professional secrecy (BfI, Hamburger Feuerwehr, BfS, THW)

Furthermore, the results of the enquiries are not sufficient to strengthen the categorisation made in chapter 2.3 or to draw a differentiated map of the interests in robust security with regard to CBRN threats. Most answers were not very specific and in many cases there was simply no response. Only the UKE claimed not to consider itself as a probable target of a CBRN attack.

But at least the yes/no estimate for various branches can be made.

Table 15 serves as a comparison of the security interest determined in the course of the investigations with regard to the CBRN risk of attack. The test results from the surveys of vdlconsult and Thermo Fisher as well as from the interviews with industry representatives themselves are represented. A further column notes who has been indicated as a sponsor in the related literature that refers to the potential and actual costs. An interest can thus be derived from this cost unit. A final evaluation of interest was carried out in the last column.

Table 14: Comparison in self-interest in robust security regarding terror acts. Questioning results and appraisals

Branche	vdlconsult	Extremus AG	Branche representative	Indicated in the literature as a cost unit	Evaluation of interest
Agriculture	Yes	Not specified	Yes	-	Strong interest
Fishing	Yes	Not specified	No investigation	-	Interest
Mining and quarrying	Not specified	Not specified	No investigation	-	No interest
Manufacturing	Yes	Yes (especially chemical industry)	No answser	Chemical and shipping industriy	Strong interest, regarding type of industry
Electricity, gas and water supply	Yes	Not specified	Yes	-	Strong interest
Construction	Not specified	Not specified	No investigation	-	No evaluation, presumably not interested
Wholesale and retail trade	Not specified	Not specified	No answer	-	No evaluation, presumably interested[73]
Hotels and restaurants	Not specified	Yes (especially hotels)	No answer	-	Interest
Transport, storage and communications	Yes	Not specified	Yes	-	Strong interest
Financial intermediation	Yes	Not specified	Yes	-	Strong interest
Real estate, renting and business activities	Not specified	Yes	No investigation	-	Interest
Public administration and defence; compulsory social security	Yes	Not specified	Yes	Yes	Strong interest
Education	Not specified	Not specified	No investigation	-	No evaluation,

[73] One can assume wholesale as a potential terror attack. See, for example, the attacks on wholesale buildings of the Kaufhaus AG by a left wing terror group on April 2,1968 in Frankfurt am Main, Germany or the attempted extortion of German wholesale company Karstadt from 1992 until 1994.

					presumably interested
Health and social work	Not specified	Not specified	No	Association of American hospitals	Presumably interested
Other community, social and personal service activities	Yes	Not specified	No answer	-	Interest
Private households with employed persons	Not specified	Not specified	No investigation	-	No evaluation, presumably not interested
Extra-territorial organizations and bodies	Yes	Not specified	Yes	-	Strong interest
Broadcasting stations, newspapers	Not specified	Not specified	No result	-	No evaluation

As a result of the investigation of the literature with regard to the specified cost unit, it may be said that while the state is generally designated as the carrier, in only a few specific cases has the state used money to protect its own government facilities. In most cases it must provide security for society as a whole and thus for the other industries as well. Hospitals as well as certain areas of industry (such as the chemical industry) were identified as non-government sponsors interested in their own security.

IV. Results

The first objective was to investigate the economic aspects of CBRN threats caused by terrorism, specifically the economic impact of a CBRN incident as well as the countermeasures previously analysed in publicly accessible academic literature. The second objective was to ascertain which sectors and companies have self-interest in robust security with regard to CBRN threats.

Due to the limited number of historic terror cases, it is necessary to look at accidents as wel. In addition to purely academic literature, other qualified sources, such as governmental publications, were used to collect a reasonable base of data. With this still limited base of cases, it is hardly possible to draw general conclusions on the likely economic impacts, even if the differences between incidents caused deliberately (mainly terror acts) and fortuitous happenings like accidents were neglected.

It is exceedingly difficult to compare the results of studies found on the economic impact of CBRN incidents. The incomparability consists both in the proportions of the incidents under consideration and in the comprehensiveness of the areas of economic impact for which are accounted. This does not only apply to hypothetical cases and scenarios, which, by their nature, have to account for a variety of assumptions. The effects often vary on several levels, even in the cases based on comparable assumptions, in particular if they refer to historic cases with well-defined effects. Consequently, the reported economic impact diversifies over a large range.

In contrast to the studies of potential scenarios, it was to be assumed that those which involve actual historical cases would contain concrete figures. This is correct to the extent that singular effects were well recorded with regard to their monetary ramifications (for example, decontamination costs). However, the number of dead or injured, for which ample literature was found, often fluctuated considerably. In case of Chernobyl, the expected number of early cancer fatalities ranges from 1,200 to 75,000. For the Bhopal accident, the number of casualties is estimated between 2,500 and 17,500.

The range of the studies, which deal with nuclear threat scenarios, was separated from the area of the other three hazardous substances. Although huge mortality figures (736,000 to 8,660,000 in Ramana (1999)) or large economic losses (DM 63 – 93 b per year *(€ 182 – 271 b per year)* in Reich (1971)) are estimated, this involves war scenarios, which can not easily be compared to acts of terrorism. A crude scaling down to a single Hiroshima sized fission bomb results in a damage estimate of 5.6m to 8.1m euros.

In the course of this study it became clear that studies in connection with biological incidents handle the largest monetary amounts. For example, in the Katarisk study the assumed possible direct damage from a biological disaster with CHF 2,010 million/year is 10 to 20 times greater than the expected amount of loss for chemical or radiological incidents. And in the case of indirect damage, biological incidents take first place in McKibbin (2006) with an estimate of 4.4 trillion USD (11% of the global GDP) for pandemic influenza. Likewise in the area of prevention and protection there is not only the most data, but the highest amounts for biological threats.

The financial resources that are used for counter-measures against terrorist attacks also exhibit huge differences. In this area there was often an overlap with goals not related to the prevention of or the protection against CBRN terror, in particular regarding an increase of general security in the chemical industry. For some activities, CBRN terror is only a minor aspect, for instance the major objective of the destruction of chemical weapons is disarmament, but at the same time this investment prevents access of chemical weapons to terrorists.

In general, the total impact costs of large incidents are very high, and are much higher that that of counter-measures. For biological threats, the indirect economic impact is assessed to be in the range of several billion to tens of billions of US dollars. The countermeasure cost range is much lower, ranging from hundreds of millions to about 10 billion US dollars. Taking the bio defence programmes alone, a few hundred thousand to tens of millions are spent by European countries for a reference year, while the USA invests about 200 million euros.

The second aim of the paper was to examine certain parties' self-interest in robust security against CBRN attacks by means of market enquiries. Third parties from the security sector were asked, as were representatives from various other industries.

As was expected, there were few responses from the surveyed industry representatives. However, it must be taken into account that a publishing research establishment such as ZNF cannot expect to receive confidential statements regarding security issues. This lies in the nature of the topic, since the knowledge of security precautions often makes circumvention of the same possible. Thus as expected, the intended investigation through direct survey resulted in limited qualitative information and in no specific data with regard to the precise precautions and the resources deployed; but a conscious refusal to make any statement at all is a clear indication of the relevance of the topic.

In contrast to this, insight into the security requirements was gained by surveying third parties. These third parties are consultants for preventive security measures and an insurance company specialized in terror attacks. They provided relevant estimates based on their own first-hand experience with customers and inquiries from various branches. By this indirect inquiry, it was guaranteed to keep the industry representatives themselves anonymous. As a result, it was found that primarily industries with a high symbolic value, as well as those representing numerous potentially threatened people, regard themselves at risk of attack and thus exhibit a security interest.

According to the majority of the literature reviewed, the state is generally designated as the carrier of the costs. In a few specific cases, the state is reported to have spent the money on the protection of its own governmental facilities. In most cases it provides security for society as a whole and thus for the various branches of industry as well. Hospitals as well as certain areas of industry (such as the chemical industry and shipping companies) were identified as non-government investors interested in their own security.

When consolidating the findings of various approaches (direct interviews, third parties, literature review) it can be assessed that a strong interest in robust security regarding CBRN terror acts can be found in the following branches: agriculture, certain industries (chemistry, shipping), electricity, gas and water supply, transport, storage and communications, financial intermediation, public administration and defence, and extra-territorial organizations and bodies. Further, some interest can be expected in the fishing industry, hotels and restaurants, real estate, renting and business activities, other community, social and personal service activities, possibly in the wholesale and retail trade sector, and the health sector. Though it appears that branches that are most endangered by possible terrorist threats with CBRN substances indicate the private sector's self interest in robust security, this study was not able to provide a solid proof thereof. In regards to this finding, the unavailability of an insurance against CBRN damages from terrorist acts is unfortunate.

Reference list

Allen 2002 "Radiation as a weapon of mass destruction" by J. Y. Allen, L. M. Matthews (Clinical Paediatric Emergency Medicine, Volume 3, Issue 4, December 2002, Pages 248-255)

Armstrong 2004 "Looking for trouble: A Policymaker's Guide to Biosensing" by R. Armstrong et al. (Center for Technology and National Security Policy, National Defense University, 2004)

Arup 2002 "Arup Security Consulting. Thinking Strategically, Assessing Risks, Defining Needs, Creating Foundation for the Future" First published in Guide to Security and Business Survival 2002

Baes 1986 "Long-term environmental problems of radioactively contaminated land" by C.F. Baes, J.P. Witherspoon et al. (Environment international, Vol. 12, pp545-553, 1986)

Berry 2007 "Preventing Nuclear Terrorism. The Moscow-Washington alliance", by K. Berry (East West Institute, Policy Paper 2/2007)

Bowonder 1987 "The Bhopal accident" by B. Bowonder (Technological Forecasting and Social Change, Volume 32, Issue 2, September 1987, Pages 169-182)

Brown 2006 "Transcendental Terrorism And Dirty Bombs: Radiological Weapons Threat Revisisted", by C. Brown (Occasional Paper No. 54, Center for Strategy and Technology, Air University, Maxwell Air Force Base, Alabama 36112, 2006)

Brück 2008 "A Survey on the Economics of Security" by T. Brück, M. Karaisl and F. Schneider (Politikberatung kompakt, 41, Deutsches Institut für Wirtschaftsforschung, Berlin 2008)

Carafano 2003 "Improving Federal Response to Catastrophic Bioterrorist Attacks: The Next Steps" by J. J. Carafano (Backgrounder #1705. Heritage Foundation, 13 November 2003)

Carafano 2004 "Dealing with Dirty Bombs: Plain Facts, Practical Solutions" J. J. Carafano and J. Spencer (Backgrounder No. 1723. Heritage Foundation, 27 January 2004)

Chalecki 2001 „A New Vigilance: Identifying and Reducing the Risks of Environmental Terrorism" by E. Chalecki. Pacific Institute, September 2001

Cosset 1997 "Cancers radio-induits: le point en 1997" by J.M. Cosset (Cancer/Radiothérapie 1997; 1:823-835)

Damveld 1996 "Chernobyl – 10 years after – The consequences" by H. Damveld (Greenpeace, Chernobyl Papers No. 4, 1996)

Davis 2002 „Are Local Health Responders Ready for Chemical and Biological Terrorism?" L. M. Davis and J. C. Blanchard. Issue Paper. RAND, 2002

Delhi Science Forum "Bhopal gas tragedy" Saket, New Delhi, 1985

de Freitas 2001 “Chemical safety and governance in Brazil” by C. M. de Freitas (Journal of Hazardous Materials 86 (2001) 135–151)

Dixon 2007 “Trade-offs Among Alternative Government Interventions in the Market for Terrorism Insurance” by L. Dixon et al.(Center for terrorism risk management policy, RAND Corporation 2007)

Enders 2006 “*The political economy of terrorism”*, by W. Enders (Cambridge University Press, Cambridge, 2006)

Extremus 2008 “ATB – Allgemeine Bedingungen für die Terrorversicherung”, Extremus AG, Köln, 2008

Fairlie 2006 “The other report on Chernobyl. An independent scientific evaluation of health and environmental effects 20 years after the nuclear disaster providing critical analysis of a recent report by the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO)” by I. Fairlie and D. Sumner (commissioned by Rebecca Harms, MEP, Greens/EFA in the European Parliament, Berlin/Brussels/Kiev 2006)

Fentiman 2004 “Factors That Affect the Cost of Low-Level Radioactive Waste Disposal” by A. W. Fentiman et al. (Ohio State University Information Extension Research Low-Level, Radioactive Waste Fact Sheets RER–66, at www.ag.ohio-state.edu/~rer/rerhtml/rer_66.html (January 21, 2004))

Field Command 1975 “Palomares summary report” by: Field Command Defence Nuclear, Agency, Technology and Analysis Directorate. Kirtland Air Force Base, New Mexico 87115 (January 15, 1975)

Folley 1952 “Incidence of Leukaemia in survivors of the atomic bomb in Hiroshima and Nagasaki, Japan” J. H. Folley et al. (The American Journal of Medicine, Volume 13, Issue 3, September 1952, Pages 311-321)

Glasstone 1964 “The Effects of Nuclear Weapons”, by S. Glasstone (Prepared by the United States Department Of Defense, published by the United States Atomic Energy Commission, April 1962, Revised Edition, Reprinted February 1964)

Gottron 2003 “Project BioShield“ by F. Gottron (Congressional Research Service, 28 April 2003)

Government Accountability Office 2003 “Hospital Preparedness. Most Urban Hospitals Have Emergency Plans but Lack Certain Capacities for Bioterrorism Response” (GAO-03-924)

Government Accountability Office 2006 “Combating Nuclear Smuggling: DHS’s Cost-Benefit Analysis to Support the Purchase of New Radiation Detection Portal Monitors Was Not Based on Available Performance Data and Did Not Fully Evaluate All the Monitors’ Costs and Benefits” (GAO-07-133R)

Gursky 2004 “Hometown Hospitals: The Weakest Link? Bioterrorism Readiness in America's Rural Hospitals“ by E. A. Gursky (Center for Technology & National Security Policy, NDU, June 2004´)

Haase 2005 “Breathing Easier?“ by L. W. Haase Century Foundation, 13 January 2005

Hicklin 2002 “Anthrax Toll May Have Been Higher Than Reported” Hicklin, A., *The Herald* (Glasgow), 5 October 2002, p.4

Hobijn 2002 “What will Homeland Security cost?” by Bart Hobijn (Federal Reserve Bank of New York, Economic Policy Review, Nov 2002)

Hopkins 1999 “For whom does safety pay? The case of major accidents” by Andrew Hopkins (Safety Science 32 (1999) 143 – 153)

House Report 2002 House Report 107-481, Public Health Security and Bioterrorism Preparedness and Response Act of 2002, 21 May 2002

Hunger 2005 “the sunshine project – Confidence Building Needs Transparency – A summary of data submitted under the Bioweapons Convention’s confidence building measures 1987 – 2003” by I. Hunger, 2005

Ilyin 1990 “Radiocontamination and possible health consequences of the accident at the Chernobyl power station” by L.A.Ilyin et al. (Journal Radiological Protection, 1990, Vol 10, p. 3 - 29)

Institute of Medicine 2002 “Biological threats and terrorism: assessing the science and response capabilities” National Academy Press, Washington, DC., 2002

Jasanoff 1988 “The Bhopal disaster and the right to know“ by S. Jasanoff (Social Science & Medicine, Volume 27, Issue 10, 1988, Pages 1113-1123)

Kataoka 2008 “The acute and long-term effects of the atomic bombing in Hiroshima and Nagasaki” by K. Kataoka (International Physicians for the Prevention of Nuclear War, 18th World Congress, Dehli, India, 2008)

KATARISK 2003 „Katarisk – Katastrophen und Notlagen in der Schweiz. Eine Risikobeurteilung aus Sicht des Bevölkerungsschutzes “ by the Swiss Federal Office for Civil-Protection (2003)

Keogh-Brown 2008 “The economic impact of SARS: How does the reality match the predictions” by M. R. Keogh-Brown, R. D. Smith (Health Policy 2008, 88, 110-120)

Kodama 2007 “Long-Term health consequences of atomic bomb radiation: RERF Life Span Study” by K. Kodama et al. (International Congress Series 1299 (2007) 73-80)

Kowalski 2003 “Immune Building Systems Technology“ by W.J. Kowalski, McGraw-Hill, New York, 2003

Kuechle 2008 "Seehäfen als neuralgische Zonen der kritischen Infrastruktur. Sicherheitstechnologische Lösungen und Arbeitsplätze am Beispiel des Hamburger Hafens" by H. Küchle (Endbericht 2008, Bonn International Centre for Conversion)

Kumar 1996 "Bhopal disaster victims' cased reopened" by Sanjay Kumar (The Lancet, Vol 347, June 15, 1996)

Lucas 2006 "Physics modelling of airborne weapons. Estimates of Outdoor Attacks using a Gaussian Plume Model" by K.V. Lucas (Information Technology & Homeland Security Project. The Richard & Rhoda Goldman School of Public Policy, University of California, Berkely, Oct. 2006)

Mahon 1987 "Managing toxic wastes—After Bhopal and Sandoz" by J. F. Mahon, P. C. Kelley
(Long Range Planning, Volume 20, Issue 4, August 1987, Pages 50-59)

Malakoff 2002 "One year after: Tighter Security Reshapes Research" by D. Malakoff (Science, Vol. 297, Sept. 6, 2002, pp. 1630-1633)

McKibbin 2006 "Global Macroeconomic Consequences of Pandemic Influenca" by W.J. McKibbin and A.A. Sidorenko (Lowy Institute for International Policy, Feb. 2006)

Miller 2003 "Bioterrorism research: New Money, New Anxieties," J. Miller (The Scientist, Vol. 17(7), p. 52, April 7, 2003)

Moodie 2003 "Preparedness for Chemical and Biological Threats to Homeland Security: A Glass Half Empty; a Glass Half Full" by M. Moodie. Paper presented at a conference, "Progress Towards Homeland Security: An Interim Report Card", sponsored by the Lexington Institute, 27 February 2003

Natarajan 1998 "^{137}Cesium-induced chromosome aberrations analyzed by fluorescence in situ hybridization: eight years follow up of the Goiania radiation accident victims" by A.T. Natarajan et al. (Mutation Research 400 _1998. 299–312)

National Academy Press 1999 "Exposure of the American People to Iodine-131 from Nevada Nuclear-Bomb Tests. Review of the National Cancer Institute report and public health implications" by Committee on Thyroid Screening Related to I-131 Exposure Board on Health Care Services Institute Of Medicine and Committee on Exposure of the American People to I-131 from the Nevada Atomic Bomb Tests Board on Radiation Effects Research Commission on Life Sciences National Research Council (National Academy Press, Washington D.C., 1999)

National Academy Press 2001 "The Impact of Low-Level Radioactive Waste Management Policy on Biomedical Research in the United States" (Washington, D.C.: National Academy Press, (2001), p. 11)

National Academy Press 2003 "Exposure of the American population to radioactive fallout from nuclear weapons tests. A review of the CDC-NCI draft report on a feasibility study" by the Committee to review the CDC-NCI feasibility study of the health consequences from nuclear weapons tests. (National research council of the national academies, the national academic press, Washington D.C., 2003)

National Defense University 2002 “Anthrax In America: A Chronology and Analysis of the Fall 2001 Attacks" (Center for Counterproliferation Research and National Defense University, Washington DC, November 2002)

National Defense University 2003 “Toward a National Biodefense Strategy: Challenges and Opportunities“
(Center for Counterproliferation Research and National Defense University, April 2003)

Nguyen 2005 “U.S. Chemical Demilitarization Stalls“ by M. Nguyen (Arms Control Today, March 2005)

Nisbet 2000 “Options for the management of Chernobyl-restricted areas in England and Wales” by A. Nisbet and R. Woodman (Journal of Environmental Radioactivity 51 (2000) 239-254)

Nussbaum 1995 “Health consequences of exposure to ionising radiation from external and internal sources: challenges to radiation protection standards and biomedical research” by R.Nussbaum and W. Köhnlein (Medicine and Global Survival, vol 2, No. 4, 1995, p71-74)

Nucleonics Week 1990 Nucleonics Week, 3 May 1990, p 1, 8 and 9

Nürbchen 2003 “Kontaminationssonde FHZ 382“, by F. Nürbchen (Thermo Electron (Erlangen) GmbH, 2003)

O'Hanlon 2002 „Protecting the American Homeland: A Preliminary Analysis” M. E. O’Hanlon et al. Washington, D.C.: Brookings Institution Press, 2002.

Olson 1971 “The Logic of Collective Action: Public Goods and the Theory of Groups” by M. Olson (Harvard University Press, 1st ed. 1965, 2nd ed. 1971)

Pangi 2002 “Consequences Management in the 1995 Sarin Attacks on the Japanese Subway System” by R. Pangi (Studies in Conflict & Terrorism, 25: 421- 448, 2002)

Pastore 1987 “The Short-Term effects of Nuclear war: The medical legacy of Hiroshima and Nagasaki” by J.O. Pastore (Preventive Medicine 16, 293-307(1987))

Ramana 1999 “Bombing Bombay? Effects of Nuclear Weapons and a Case Study of a Hypothetical Explosion” by M.V. Ramana (IPPNW Global Health Watch Report Number 3, 1999)

Reeves 1999 “Radiation injuries” by G.I. Reeves (Environ Emerg. 15: 457-473, 1999)

Reich 1971 „Die wirtschaftlichen Schäden eines atomaren Krieges in der Bundesrepublik Deutschland und ihre Folgen“ by U. Reich in „Kriegsfolgen und Kriegsverhütung“, edited by Carl Friedrich von Weizsäcker (3rd, extended edition, Carl Hanser Verlag München 1971)

Royal Society 2008 “Detecting nuclear and radiological materials” (Royal Society policy document 07/08, March 2008)

Sandler 2008 “Copenhagen Consensus 2008 Challenge Paper. Terrorism” by T. Sandler (Copenhagen Concensus Center, 2008)

Satyanand 2008 “Aftermath of the Bhopal accident” by Tara Satyanand (The Lancet, Vol 371, June 7, 2008)

Schuler 2004 “Billions for Biodefense: Federal Agency Biodefense Funding, FY2001–FY2005” A. Schuler (Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science 2, no. 2 (2004): 86)

Schneidmiller 2005 “Terrorist Threat to U.S. Chemical Facilities Can Be Lowered, Not Eliminated, Officials Say“ by C. Schneidmiller. Global Security Newswire, 7 September 2005.

Scott 1995 “Dark after Chernobyl? – Closing former Soviet power reactors” by M. J. Scott et al. (Energy Policy 1995 Volume 23 Number 8, pp 703-717)

Schwermer 2007 “Ökonomische Bewertung von Umweltschäden. Methodenkonvention zur Schätzung externer Umweltkosten“, by S.Schwermer (Umweltbundesamt, April 2007)

Seigle 2002 “Feds Could Make Bioterror ‘Impossible’, Expert Says,” G. Seigle (Global Security Newswire, April 9, 2002)

Shea 2004 “Terrorism: Background on Chemical, Biological, and Toxin Weapons and Options for Lessening Their Impact“ D. A. Shea (CRS Report for Congress, 01 December 2004. Posted on the Federation of American Scientists website)

Sherman 2007 “Avoiding the Plague: An Assessment of US Plans and Funding for Countering Bioterrorism“ by R. Sherman (Center for Strategic and Budgetary Studies, April 2007)

Shrivastava 1994 “Technological and Organizational Roots of Industrial Crises: Lessons from Exxon Valdez and Bhopal“ by P. Shrivastava (Technological Forecasting and Social Change, Volume 45, Issue 3, March 1994, Pages 237-253)

Sonntag 1971 „Mathematische Analyse der Wirkungen von Kernwaffenexplosionen in der BRD“ by P. Sonntag in „Kriegsfolgen und Kriegsverhütung“, edited by Carl Friedrich von Weizsäcker (3rd, extended edition, Carl Hanser Verlag München 1971)

Sriramachari 1997 “The lessons of Bhopal (Toxic) MIC gas disaster scope for expanding global biomonitoring and environmental specimen banking” by S. Sriramachari and H. Chandra (Chemosphere, Volume 34, Issues 9-10, May 1997, Pages 2237-2250)

Stern 2002 „Dreaded Risks and the Control of Biological Weapons“ by J. Stern (International Security, Winter 2002/03)

Steinhäusler 1988 “Chernobyl and its radiological and socioeconomic consequences for the province of Salzburg, Austria” by F. Steinhäusler, W. Hofmann, F. Daschil and B. Reubel (Environment International, Vol 14, pp 91-111, 1988)

Thermo 2007 “Rad EYE. The next generation of Advanced Radiation Meters. Draft” (Thermo Electron (Erlangen) GmbH, 2007)

Thermo 2008 “Referenzliste Deutschland / Reference List Germany Radioaktivitätsmessanlagen / Radioactivity Monitoring System (Thermo Electron (Erlangen) GmbH, 2008)

Trust for Americas Health 2007 “Ready or Not? Protecting the public’s health from diseases, disasters and bioterrorism” Trust for Americas Health, December 2007

Tveten 1998 “Economic Consequences of the Chernobyl Accident in Norway in the Decade 1986-1995” by U. Tveten, L. I. Brynildsen, I. Amundson and T. D. S. Bergan (J. Environ. Radioactivity, Vol 41, No 3, pp 233-255, 1998)

UNO (2006) International Standard Industrial Classification of All Economic Activities, Rev.4 Draft,

Varma 2006 “The Bhopal accident and Methyl and Methyl Isocyanate Toxicity” by D. Varma and S. Mulay (Toxicology of Organophosphate & Carbamate Compounds, 2006, Pages 79-88)

Vogel 2007 “Rays as weapons” by H. Vogel (European Journal of Radiology 63 (2007) 167-177)

von der Lippe 2005 “Advanced Building Security. TAT Workshop. Security & safety Middle East 2005”, by J.K. von der Lippe, Abu Dhabi, 16th November 2005

von Weizsäcker 1971 „Kriegsfolgen und Kriegsverhütung“, edited by Carl Friedrich von Weizsäcker (3rd, extended edition, Carl Hanser Verlag München 1971)

Wein 2005 “Analyzing a bioterror attack on the food supply: The case of botulinum toxin in milk“ by L.M. Wein and Y. Liu (Proceedings of the National Academy of Sciences of the United States of America, Vol. 102, No. 28, pp. 9984-9989, 2005)

Wetter 2001 “Hospital Preparedness for Victims of Biological and Chemical Terrorism,” by D. C. Wetter et al. (American Journal of Public Health, Vol. 91, No. 5 (2001), pp. 710–716)

White 2003 “Terrorism: 2002” by J.R. White (update, 4th ed., Wadsworth/Thomson Learning, Belmont, CA, 2003)

Zimmermann 2004 “Dirty Bombs: The Threats Revisited” by P. D. Zimmerman with C. Loeb. (Defense Horizons, January 2004. Center for Technology and National Security Policy, National Defense University)

Acknowledgements

Thanks to the Consultant Team:

- Prof. Dr. Michael Brzoska, economist, scientific principal of the Institut für Friedensforschung und Sicherheitspolitik an der Universität Hamburg (IFSH). Expertise: macroeconomic questions in security research.

- Prof. Dr. Götz Neuneck, physicist, head of the Interdisziplinäre Forschungsgruppe Abrüstung, Rüstungskontrolle und Risikotechnologien (IFAR²) Expertise: nuclear and radiological threats.

- Dr. Iris Hunger, biochemist, leader of the Research Group for Biological Arms Control of the Zentrum für Naturwissenschaft und Friedensforschung (ZNF). Expertise: biological threats.

- Prof. Dr. Volkmar Vill, chemist, Department of chemistry of the Universität Hamburg. Expertise: chemical threats.

- Stefan Röhrig, physicist, Senior Liability-Risk Consultant AIG (American International Group) Europe, Frankfurt. Expertise: microeconomic questions of security research, especially regarding industry.

A further thanks to:

- Uwe Polley (chief librarian of the IFSH), literature research
- Sarah von Kaminietz Julie Ann Daludado and James Hands (student assistants)
- Textra Hamburg (Correction agency)

Appendices

Appendix A: Questionnaire

Questions to direct effects

- Is your facility a potential direct CBRN assault?
- Are there more than statutory security standards regarding the direct consequences of a CBRN attack?
- Are these extra security arrangements preventive technical arrangements?
- If so, what are these technical arrangements?
- Are these extra security arrangements preventive logistical or personnel arrangements?
- If so, what are these logistical or personnel arrangements?
- Are these extra security arrangements reactive technical arrangements?
- If so, what are these technical arrangements?
- Are these extra security arrangements reactive logistical or personnel arrangements?
- If so, what are these logistical or personnel arrangements?

Questions to indirect effects

- Are there possible effects on your facility caused in a CBRN attack on other branches or sectors?
- Are there more than statutory standards regarding the indirect consequences of a CBRN attack?
- Are these extra security arrangements preventive technical arrangements?
- If so, what are these technical arrangements?
- Are these extra security arrangements preventive logistical or personnel arrangements?
- If so, what are these logistical or personnel arrangements?
- Are these extra security arrangements reactive technical arrangements?
- If so, what are these technical arrangements?
- Are these extra security arrangements reactive logistical or personnel arrangements?
- If so, what are these logistical or personnel arrangements?

Appendix B: Cost Matrices

Costs caused by chemical, biological and radiological incidents

Table 15: Costs caused by the impact of chemical, biological and radiological incidents collated in all literature used

	Chemical	Biological	Radiological
First response			
Recovery, reconstruction, restoration	CHF 125 m /year *(87.39 m €/year)* 2.86×10^{-02} without risk aversion and CHF 190 m /year *(132.83 m € /year)* with risk aversion **(3.1)**	CHF 2,010 m /year *(1405.05 m €/year)* 4.59×10^{-01} without risk aversion and CHF 7,751 m /year *(5418.92 m €/year)* with risk aversion **(3.2)**	$US 300 *(254.42 €)* or more per cubic foot **(1)** More than $US 40 b *(33.92 b €)* 3.42×10^{-01} **(2)** CHF 118 m /year *(82.49 m €/year)* 2.70×10^{-02} without risk aversion and CHF 1,546 m /year *(1080.85 m €/year)* with risk aversion **(3.3)** Several billion or even trillion $US **(4.2)**
Indirect damage costs	$US 500 m up to $US 19 b *(398.22 m € up to 15.13 b €)* (3.79×10^{-03} – 1.44×10^{-01}) **(5.1)** $US 58 b *(46.19 b €)* 4.4×10^{-01} **(5.2)**	$US 500 m up to $US 19 b *(398.22 m € up to 15.13 b €)* (3.79×10^{-03} – 1.44×10^{-01}) **(5.1)** $US 58 b *(46.19 b €)* 4.4×10^{-01} **(5.2)** $US 2 b *(1.78 b €)* 1.91×10^{-02} **(6)**	$US 500 m up to $US 19 b *(398.22 m € up to 15.13 b €)* (3.79×10^{-03} – 1.44×10^{-01}) **(5.1)** $US 58 b *(46.19 b €)* 4.4×10^{-01} **(5.2)**

	$US 630 b *(488.94 b €)* 4.56 **(8.1)**	$US 4.4 tr *(3.5 tr €)* 10.6 **(7.1)** $US 400 b *(310.44 b €)* 2.9 **(8.2)** $US 3.7 b *(3.23 b €)* 2.41 **(9)**	$US 63 b *(48.89 b €)* 4.56x10^{-01}**(8.3)**

Table 16: Killed and injured people caused by the impact of chemical, biological and radiological incidents collated in all literature used

Killed people by CBRN event	12 **(10)**	142,200,000 **(7.2)**	4 **(11)**
Injured people by CBRN event	Some hundred **(10)**	400,000 **(12)**	129 **(13)**

Costs for counter-measures against chemical, biological and radiological incidents

Table 17: Costs for counter-measures against chemical, biological and radiological incidents collated in all literature used

	Chemical	Biological	Radiological
Prevention	10b $US *(7.76 b €)* 7.24x10^{-02} **(14)** $US 1.406 b *(1.16 b €)* 1.13x10^{-02} **(18)** more than $US 2 b *(1.64 b €)*	10b $US *(7.76 b €)* 7.24x10^{-02} **(14)** over $US 7 b *(5.43 b €)* 5.07x10^{-02} **(15.1)** + additional nearly $US 6 b *(4.66b €)* 4.35x10^{-02} **(15.2)** $US 70 m/year *(54.33 m €/year)* 5.07x10^{-04} **(16)** $US 476 m *(369.42 m €)* 3.45x10^{-02} **(17)**	10b $US *(7.76 b €)* 7.24x10^{-02} **(14)**

	1.13x10^{-02} **(20)**	over $US 11 b *(9.6 b €)* 1x10^{-01} **(19)** approximately $US 1.5 b *(1.31 b €)* 1.37x10^{-02} **(21)** $US 3 b *(2.62 b €)* 2.74x10^{-02} **(22)** $US 1.748 b *(1.53b €)* 1.59x10^{-02} **(23)** $US 240 m *(213.86 m €)* 2.29x10^{-03} **(25.2)**	200 m € 1.04x10^{-03} **(24)** > $US 500 m *(398.22 m €)* 3.8x10^{-03} **(4.1)**
Protection	$US 72 b *(64.16 b €)* 6.88E^{-01} **(27)** $US 40 b *(35.64 b €)* 3.82x10^{-01}	$US 130,000 *(116,000 €)* **(26)** $US 72 b *(64.16 b €)* 6.88x10^{-01} **(27)** approximately $US 125 m *(109.06 m €)* 1.14x10^{-03} **(28)** $US 14.5 b +$US 7.6 b *(11.91 b* *+ 6.24 b €)* (1.17x10^{-01} + 6.12x10^{-02}) **(29)** $US 40 b *(35.64 b €)* 3.82x10^{-01} **(30.1)**	$US 72 b *(64.16 b €)* 6.88x10^{-01} **(27)** $US 40 b *(35.64 b €)* 3.82x10^{-01}

	(30.1) $US 1.555 b *(1.41 b €)* 1.54x10^-02^ **(31)**	+ $US 5.9 b *(5.26 b €)* 5.64×10^{-02} **(30.2)** $US 2.9 b *(2.58 b €)* 2.77×10^{-02} **(25.1)** $US 1.555 b *(1.41 b €)* 1.54×10^{-02} **(31)** $US 60 m *(52.35 m €)* 5.47×10^{-04} **(32)**	**(30.1)** $US 1.555 b *(1.41 b €)* 1.54×10^{-02} **(31)**
Prearedness	$US 10 to $US 30 b/year *(8.48 b to 25.44 b €/year)* (8.56×10^{-02} – 2.57×10^{-01}) **(33)**	$US 10 to $US 30 b/year *(8.48 b to 25.44 b €/year)* (8.56×10^{-02} – 2.57×10^{-01}) **(33)**	

In reference points 5.1, 5.2, 14, 27, 30.1, 31 and 33 costs are not specified for one substance but for all three substances together.

See below an explanation of the costs in the matrices:

1) Removing low-level radioactive waste from a biomedical research facility to an appropriate storage facility.[74]

[74] Carafano (2004)

2) Cost estimates to restore lower Manhattan after the September 2001 attack range up to 40 billion USD plus loss of economic activity. The consequences of a large or super RDD might well be more costly.[75]

3) Costs for recovery, reconstruction and restoration caused by a chemical incident in Switzerland with nationwide dimension: 125m CHF/year (without risk aversion[76]) and 190m CHF/year (with risk aversion) – **(3.1)**
Costs for recovery, reconstruction and restoration caused by a biological incident in Switzerland with nationwide dimension: 2010m CHF/year (without risk aversion) and 7751m CHF/year (with risk aversion) – **(3.2)**
Costs for recovery, reconstruction and restoration caused by a radiological incident in Switzerland with nationwide dimension: 118m CHF/year (without risk aversion) and 1546m CHF/year (with risk aversion) – **(3.3)**. [77]

4) The total amount for the introduction of detectors for locating illegally transported radioactive substances. Ports in the United States, the railroad system in the US and monitoring organisations are to be equipped with these detectors. In addition, the costs for training suitable technical personnel and for maintenance are taken into account **(4.1)**. In contrast, the possible damage from contamination with a radiological bomb is indicated as amounting to several trillion or quintillion U.S. dollars **(4.2)**.[78]

5) U.S. - loss of earnings for a large port not working for ten days **(5.1.)** loss for the whole U.S.-economy **(5.2.)**. [79]

6) The pneumonic plague that broke out in Surat, India, in 1994 – costs for India because of its impact on tourism and exports.[80]

7) Loss of GDP on a global level **(7.1)** while 142.2 m people dying **(7.2)**.[81]

8) Expected total financial loss in a large metropolitan area on the US-Atlantic coast in the event of outdoor anthrax **(8.1)**, a radiological attack **(8.2)** and an indoor SARIN attack **(8.3)**.[82]

9) GDP-loss Hong Kong: 3.7 b $US by SARS epidemic in 2003.[83]

10) Number of dead and injured people resulting from the SARIN attack on the Japanese Subway System in 1995.[84]

11) Number of people killed by ^{137}Cs accident in Goiania (Brazil) in 1987.[85]

---

75 Zimmermann (2004)

76 Damages are calculated according to occurrence probability and the extent of loss under the assumption of risk neutrality. For values with risk aversion, an additional factor is whether a risk has a high extent of loss or not. If it does, a "risk tax" is assumed. This can be an additional verbal comment or the modelling of an aversion factor. See Schwermer (2007).

77 KATARISK (2003)

78 Brown (2006)

79 Küchle (2008)

80 Stern (2002)

81 McKibbin (2006)

82 Dixon (2007)

83 Keogh-Brown (2008)

84 Pangi (2002)

12) Casualties caused by a bioterrorist attack on the food industry: contamination of milk with botulinumtoxin.[86]

13) Number of people accidentally exposed to ^{137}Cs in Goiania (Brazil) in 1987.[87]

14) U.S. – costs for destroying Russian weapons of mass destruction and supporting systems.[88]

15) Amount of money the Department of Health and Human Services has invested to prepare states and local public health departments and hospitals for public health emergencies and acts of bioterrorism since 9/11 **(15.1)** and since FY 2006, specifically for pandemic influenza preparedness, of which 600m USD has gone to state and local health departments **(15.2)**. [89]

16) U.S. - Implementing a protocol that allowed for access to existing or suspected facilities where biological-weapons-related work might be conducted (including no-notice inspections) could go far toward improving bio security worldwide. [90]

17) In response to the terrorists attacks of 2001, the health resources and services administration distributed 125m USD in federal funds during 2002 to prepare hospitals for mass-casualty events, particularly bioterrorism. In 2003, the funding level increased to 498m USD and 515m USD has been allocated for 2004.[91]

18) The president's fiscal year 2006 budget request for chemical demilitarisation programmes across the United States.[92]

19) Association of American Hospitals, cost estimation for preparing the nation's hospital facilities for biotoxin attacks. [93]

20) The U.S. chemical industry; to increase security since the Sept. 11 attacks.[94]

21) National Institute of Allergy and Infectious Diseases bioterrorism research six-fold increased in the fiscal year 2003.[95]

22) The fiscal year 2004 budget for biodefense medical countermeasures, including 1.3 billion USD for pharmaceutical purchases and stockpile maintenance and over 1.6 billion USS to develop new products.[96]

---

85 de Freitas (2001)
86 Wein (2005)
87 Natarajan (1998)
88 Berry (2007)
89 Trust for Americas Health (2007)
90 Sherman (2007)
91 Gursky (2004)
92 Nguyen (2005)
93 Carafano (2003)
94 Schneidmiller (2005)
95 Gottron (2003)
96 National Defense University (2003)

23) The Bush administration requested more than a six-fold increase in bioterrorism research. Of this amount, 978m USA was to be for basic and applied research (441m USD for basic research; 195m USD for clinical research, and 342m USD for therapeutics, drugs and vaccines), 250m USD for procurement of anthrax vaccine, and 521m USD for construction of and renovation of Biosafety Level 3 and Biosafety Level 4 laboratories.[97]

24) European Commission: for the prevention and detection and response to illicit trafficking of nuclear and radiological material.[98]

25) In January 2002, President Bush signed into law a supplemental bioterrorism appropriation for states to help prepare their public health infrastructures for biological attacks **(25.1)**. On January 25, 2002, DHHS Secretary Tommy Thompson announced the release of the first instalment to create regional hospital response plans for a bioterrorist attack **(25.2)**.[99]

26) Louisiana State University – protection of laboratories with biological substances.[100]

27) Total direct costs of homeland security in the USA.[101]

28) The Bioterrorism Hospital Preparedness Program, administered by HHS's Health Resources and Services Administration (HRSA), provided funding in the fiscal year 2002 through cooperative agreements to states and eligible municipalities to enhance the capacity of hospitals and associated health care entities to respond to bioterrorism.[102]

29) Total spending on civilian biodefence—including scientific research, vaccine production, and food safety initiatives—for fiscal year 2004, with an additional amount requested in the president's fiscal year 2005 budget.[103]

30) Amount after 11 September 2001 that Congress and the White House requested **(30.1)** in emergency funds to address homeland security issues, including biodefence.
In additional to this supplement, the President proposed a substantial increase in funding for future efforts to counter bioterrorism. The proposed 2003 budget requests **(30.2)** for improved biodefence, an increase of more than 300 percent over the previous year, targeted on improvements in three areas: infrastructure, response, and science.[104]

31) In the fiscal year 2001, requested amount of money to protect against chemical, biological, radiological and nuclear attack by the US government.[105]

32) Costs for a deployment of a biosensor network in 31 US-American cities. [106]

33) Costs to provide sufficient depth of response to reduce a chemical, biological, or toxin attack's effectiveness.[107]

---

97 Moodie (2003)
98 Royal Society (2008)
99 Davis (2002)
100 Malakoff (2002)
101 Hobijn (2002)
102 Government Accountability Office (2003)
103 Haase (2005)
104 National Defense University (2002)
105 Chalecki (2001)
106 Armstrong (2004)
107 Shea (2004)

A further example of annual expenditure of different countries on biodefence programmes is shown in Table 18.

Table 18: Information on bio defence programmes. [108]

State	First and last year of declaration	Level of funding declared in the most current submission
Australia	1995 / 2003	0.9 m € *(0.914 m €)*
Belarus	1995 / 2003	0.14 m € *(0.14 m €)*
Belgium	1999 / 2002	6.16 m € *(6.25 m €)*
Canada	1992 / 2003	31.09 m € *(31.57 m €)*
China	1992 / 2003	0.2912 m € *(0.30 m €)*
Finland	1992 / 2003	0.07 m € *(0.07 m €)*
France	1992 / 2002	8 m € *(8.13 m €)*
Germany	1992 / 2003	5.2 m € *(5.28 m €)*
India	1997 / 1997	0.04 m € *(0.04 m €)*
Japan	2002 / 2003	0.02 m € *(0.02 m €)*
Netherlands	1992 / 2003	3.35 m € *(3.40 m €)*
Norway	1992 / 2003	0.29 m € *(0.29 m €)*
Russia	1992 / 2003	4.95 m € *(5.02 m €)*
South Africa	2000 / 2003	0.0096 m € *(0.0097m €)*
Spain	1996 / 2003	0.721 m € *(0.732 m €)*
Sweden	1992 / 2001	1.58 m € *(1.60 m €)*
Switzerland	1996 / 2003	0.69 m € *(0.70 m €)*
United Kingdom	1992 / 2003	36.92 m € *(37.50 m €)*
USA	1992 / 2003	196.02 m € *(199.1 m €)*

These monetary amounts were collected in "the sunshine project". The report by Hunger (2005) presents an overview of data submitted by state parties to the Biological Weapons Convention (BWC) in the course of the annual information exchange, the so-called Confidence Building Measures.

It is striking that, for example, the expenditure of the USA on its biodefence programme is approximately as high as the amount spent by the European Union for protection against radiological threats[109]. The costs expended by the Japanese government for biodefence programmes are amazingly low compared with other industrial nations.

[108] Hunger (2005)
[109] Royal Society (2008)

Appendix C: The Bhopal accident

In 1984, one of the biggest chemical accidents occurred in Bhopal, India. In the early hours the December 3rd, forty tons of methyl isocyanine leaked from an industrial plant, due to a technical failure. 3,000-8,000 people died directly and approximately 20,000 died in the aftermath of this accident. Nearly 150,000 people are suffering from long-term effects of the accident.

Table 19: The Bhopal accident and the economic impact

Recovery, reconstruction, restoration	Compensation payments by UCC[110]: 470m USD *(464.92m €)*6.01×10^{-03}[111] Payments by the Indian Government in 1985 for food assistance and cash grants to families of the deceased: 40m USD *(49.06m €)* 7.84×10^{-04} [112]
Indirect damage costs	Claimed costs by Indian Government: 500 USD *(398.22 €)* per person suffering from long-term effects of the accident. 2,000 USD *(1592.86 €)*1.40×10^{-08} per family which lost one of their members in the accident [113] Union Carbide Corporation share price dropped from 60 to 30 USD *(56.92 € to 28.46 €)* in the period immediately after the accident [114] Litigation costs: claims amounting to 3 billion USD *(3.81b €)* 6.33×10^{-02}[115]

Table 20: The Bhopal accident - dead and injured people

People killed	5,000 – 8,000 [116] 17,500 [117] 3,000 [118] 3,000 [119] 2,000 [109] 2,500 [120]
People injured	200,000[114] 200,000 119[6] 200,000 [109]

[110] Union Carbide Corporation
[111] Kumar (1996)
[112] Jasanoff (1988)
[113] Satyanand (2008)
[114] Hopkins (1999)
[115] Mahon (1987)
[116] Delhi Science Forum (1985)
[117] Varma (2006)
[118] Sriramachari (1997)
[119] Shrivastava (1994)
[120] Bowonder (1987)

In his paper, Hopkins examines the question whether the often-used term by government agencies that “safety pays” is really effective in the case of catastrophic hazards. Among his examples of historic catastrophic incidents, he looks at the Bhopal accident and the economic consequences for the Union Carbide Corporation (UCC[121]). He concludes that in the aftermath of the Bhopal accident, the UCC benefited because of aggressive restructuring of the company and the company’s new focus on its core business. All these activities made the company more profitable than ever.

[121] today Dow Chemical

Appendix D: The Chernobyl accident

In 1986, one of the worst radiological accidents occurred in Chernobyl, USSR, today's Ukraine. Due to a meltdown and explosion in a nuclear power plant, an extensive area around the plant was highly contaminated with radioactive material. Thousands of people had to be evacuated. The aftermath of the radioactive contamination was traceable in several European countries.

Table 21: The Chernobyl accident and the economic impact

Recovery, reconstruction, restoration	Cleaning activities, decontamination and building of the sarcophagus as well as over 20,000 new houses and 15,000 flats in the Ukraine: 17 billion USD *(16.82b €)* $2.17x10^{-01}$ [122] Direct costs in farming, milk industry and for measurement equipment in slaughter houses: 4.9m USD *(6.01m €)* $9.6x10^{-05}$[123] Total costs of mitigating all Chernobyl related damages in Norway: ~ 300m USD *(288.70m €)*$5.88x10^{-03}$ [124]
Indirect damage costs	Macroeconomic loss of Belarus, 1986 up to 2015: 235b USD *(288.23b €)* 4.6 [119] Loss in Sweden related to agriculture and cattle breeding: 145m USD *(177.84m €)* $2.84x10^{-03}$[119] The Norwegian government spends 3m $US *(3.68m €)* $5.88x10^{-05}$ per year on measuring radioactivity in meat [119] The German government spent 300 m $US *(296.77 m €)* $3.3x10^{-02}$ as a concession to losses by the cattle breeding, agricultural and horticultural industries. A further 44 m $US (*43.53 m €*) $4.81x10^{-02}$ were spent on the processing of contaminated milk. [119] Indirect damages in farming: 0.71m USD *(0.68m €)* $8.12x10^{-06}$ [120] Inspection and monitoring of sheep in Wales related to radioactive contamination: £ 1.30 *(2.71 €)* per sheep [125]

Containment of residual radioactivity	Costs of closure of Chernobyl-type nuclear power plants: 1 – 16 billion USD *(1.01b – 16.31b €)* $1.35x10^{-02}$ – $2.16x10^{-01}$[126]

[122] Damveld (1996)
[123] Steinhäusler (1988)
[124] Tveten (1998)
[125] Nisbet (2000)
[126] Scott (1995)

Table 22: The Chernobyl accident - dead and injured people

People killed immediately after the accident	47 [127]
Expected cases of thyroid cancer	18,000 – 66,000 [124]
Thyroid cancer cases	> 4,000 [124]
Expected cases of cancer deaths	30,000 – 60,000 [124] 50,000 - 75,000 [119] 1,200 [124]
Dead liquidators[128]	300 [129] 20,000 [130]

Both catastrophes (Chernobyl and Bhopal) were accidents, but they could have been caused by a terror act. For this reason the consequences, especially the economic effects of reconstruction, rebuilding and restoration, would have been the same.

It is striking that there is a large range, even when it comes to the results in the two studies that treat the effects of Bhopal and Chernobyl. Here it may be said that very concrete values were able to be determined as long as the purely monetary costs, which resulted from the events, were concerned. However, only individual areas were examined. In contrast, the data fluctuated considerably in both cases with regard to the number of dead or injured. Thus the data on the number of victims in Bhopal ranged from 2,500 to 17,500, and in the case of the Chernobyl disaster the data on the number of victims subsequently afflicted with or who died from cancer ranged from 1,200 to 75,000.

[127] Fairlie (2006)
[128] These so called liquidators were special forces for first response and for the building of the sarcophagus.
[129] Nucleonics Week (1990)
[130] Nussbaum (1995)