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THE IMPACT OF POTENTIAL EMERGENCIES AND TERRORISM ON THE POPULATION AND BUSINESS SECTOR WITH PARTICULAR EMPHASIS ON THE USE OF RADIOLOGICAL WEAPONS

Abstract: An overview of natural and anthropogenic emergencies on society as a whole, and specifically concentrating on the persons affected, business communities and other spheres of the economy affected by the terrorism, with special emphasis on radiological attacks, is presented. Special attention is paid to a possible terrorist attack using high activity radioactive sources, commonly known as a dirty bomb or a so-called radioactive dispersion device (RDD). Although this kind of terrorism has not yet been applied, everything suggests that one has to be prepared for such an attack in the near future. Many terrorist groups have already showed their interest in acquiring suitable radiological sources to construct a RDD. This is why such materials should be kept secured and under strict regulatory control to avoid access by unauthorized persons who may steal them and use them for malicious actions. The impact of terrorism in terms of economic losses and costs as well as health consequences on the public is discussed in some detail.
Keywords: emergency, terrorism, dirty bomb, radioactive source, business, economic losses, population.
JEL Classification: O 33

Introduction

There exist many different kinds of emergencies which may endanger human life and the environment as well as business, including production, trade, transport, services, safety, and other important spheres of life. In principle, basic emergencies may be characterized as follows:

A. Natural disasters:

- Cosmic disasters (extra-terrestrial impact, solar flares),

- Meteorological disasters (storm, hail, drought, tornado, hurricane, extreme frost and dryness),
- Geological disasters (volcanic eruption, avalanche, earthquake, tsunami, rock slide), and
- Other disasters (epidemics and pandemics including coronavirus, famine, locusts, flood, fire); and

B. Anthropogenic disasters:

- Industrial disasters (nuclear accident, radiation accident, chemical accident, mining accident),
- Traffic accidents (road, rail, air, sea, space),
- Violent acts (war, terrorist attack, sabotage, arson), and
- Infrastructure outage (power interruption, telecommunication outage, water supply).

Any of these serious emergency situations could negatively affect such areas as:

- Human life and health (restriction of personal freedom, strain on health services, isolation of people, shortage of protective equipment, compulsory evacuation, worsening of living conditions),
- Environment (infestation, contamination, disease spread, crop failure),
- Critical infrastructure (disruption of essential services, problems in effective functioning of government etc.),
- Industrial production (discontinuation, restriction, suspension, transformation),
- Agricultural activity resulting in food shortages,
- Travel (reduction, suspension)
- Health care and other essential services, and
- Business (trade restriction and restraint, deterioration of economic activities and development, disruption of economic relations, unemployment, bankruptcy).

Some recent studies have shown that the actual form of economic impacts of terrorist attacks varies significantly from usual events and even other calamities. It appears that subsequent anti-terrorist initiatives introduced were more expensive than the direct destruction caused by such an attack. In addition to direct remediation costs, one has to also take into account indirect effects, including macroeconomic effects. There are many indications that terrorists have been active during the last few years and that we cannot exclude their attacks using CBRN or explosive means, where the use of a radiological weapons and drones for their delivery poses a great/major challenge (Enoizi, J. 2019).

Applications of radiation and nuclear technologies: potential negative aspects

In any use of ionizing radiation, mainly alpha, beta, neutrons and gamma, or nuclear reactors, there is always the potential of irradiation (exposure) of persons or releases of radioactive material into the environment. Under normal operations, these consequences are brought to the very minimum and the possible impact is kept under control, ensuring that the personal exposures or contamination is below strict limits or reference levels set by international standards and national legislation. Thus, potential health detriments of affected persons (workers, patients and members of the public) is so low that they are comparable with the level of risk associated with other professions and with everyday life. Since the use of radiation and nuclear technologies is very beneficial, the advantage many times exceeds the relatively minor negative effects. The aim of protection under such circumstances is to keep the exposure (radiation doses) as low as practically available, and always below the limits mentioned, but still allowing the advantageous use of these technologies.

On the other hand, we have to consider and be ready for incidents or accidents, and here the main task consists in the prevention of such events and the minimization of their consequences, where the main task is to return everything to the normal conditions. All these actions and interventions have to be planned and carried out in accordance with the relevant safety and security standards. The costs of such operations may be quite substantial and the impact of terrorist attacks on the health of affected people is another important issue to be considered.

The impact on the health of people affected by radiation can be summarized by the following effects expected during normal and emergency situations:

Stochastic effects (normal situations)

- Radiation natural background (around 2-4 mSv per year),
- Exposure due to the use of radiation and nuclear technologies under normal conditions (population limit 1 mSv/y and workers 20 mSv/y),
- Monitoring of the radiation situation (control of prescribed doses and radiation levels),
- Recommendations and regulations (aimed at complying with limit values).

It should be noted that Sv (sievert) is a unit of radiation dose, where 1 mSv = 0.001 Sv. Just for comparison, the average annual natural radiation background is 2.4 mSv, an X-ray medical examination may result in an exposure in the range of 0.1-5 mSv. However, high exposure at 4 Sv can lead to the death of 50% exposed persons (Sabol, J. 2019).

Deterministic effects (emergencies)

- High-dose exposure (due to radiation and nuclear accidents),
- Radiation sickness and serious damage to the health of affected persons,
- Radiation death of persons exposed to high intensity external or internal radiation.

Principles of radiation protection

- Compliance with applicable laws, ordinances, regulations and instructions of the supervisory authority,
- Protection of persons (under normal conditions, radiation consistent with stochastic effects; prevention of incidents and accidents, dealing with emergencies to minimize their impact on the population, the environment and the workplace, avoidance of sabotage or terrorist attacks which could result in high personal exposure and the necessity to decontaminate affected sites).

Radiation and nuclear accidents

There is never absolute certainty in using any technology without, although in most cases negligible, some probability that something may go wrong. Throughout the atomic age there have been a number of accidents involving strong radioactive sources such as are used in radiotherapy for treating cancer patients and at nuclear reactors serving as a source of energy in the production of electricity at nuclear power plants. Such accidents are always scrutinized and lessons learned to avoid similar occurrences and, at the same time, actions are taken to improve radiation equipment and nuclear installations.

Radiation accidents are characterized by the following features:

- Danger (human exposure, local radioactive contamination),
- Radioactive emitters (closed and open; radionuclides used for medical, industrial and research purposes; examples: radiotherapy, industrial radiography, traffic accidents during the transport of radioactive sources),
- Radioactive wastes (excessive radioactive material leakage from waste repositories),
- Radiation generators (accidents at workplaces of X-ray accelerators).

One of the most serious accidents involving a radioactive source occurred in 1987 in Goiania (IAEA. 1988), Brazil, after a forgotten radiotherapy source was found in an abandoned radiotherapy hospital in the city. After the source containing radioactive Cs-137, the activity of which was about 50 TBq was found in a powdered form, several buildings and the heavy radioactive contamination of parts of the city had to be decontaminated. A number of people were exposed to high doses; this resulted in the death of four persons and injury from radiation of many others. Since the cause of these injuries was discovered only after a few days, more than 100 thousand people suspected of radioactive contamination had to be monitored and part of the city had to be decontaminated, including the destruction of some buildings and the removal of the upper layer of the contaminated soil (Fig. 1). The consequences of the Goiania accident showed us what could be expected when a similar source is deliberately used as a weapon for attacking groups of people or even to assassinate a specific person.

Total expenditures for monitoring, clean-up and treatment of the victims by the federal government amounted to several million USD. The impact on agricultural products was also dramatic. Within two weeks of the event, the wholesale value of components of the state's agricultural production fell by as much as 50%. During the first three months following the accident, there was a very definite impact on the number of homes sold, home sale prices, rental prices, and land prices. The clean-up activities were basically terminated when the level of decontamination reached "an acceptable level of safety", which was not clearly specified and caused some technical controversy (Petterson, J.S. 1988).

a)

b)

Figure 1: **a) Monitoring of people suspected of radioactive contamination, b) decontamination of a large area of the city, including the demolition of some buildings and removal of the upper layer of contaminated soil.**

Source : PETTERSON, J.S. 1988

Contrary to atomic weapons, a radiological weapon has no mechanical destruction power or emitted strong pulse; it can, however, affect a person by direct external radiation and internal exposure of persons as well as the contamination of major surroundings of the site which would not be easy to fully decontaminate. This contamination depends on many factors, such as type and form of the radioactive sources used and environmental conditions. The situation following the explosion of a dirty bomb will result in surface and air contamination which will cause exposure to persons by external radiation and inhalation of contaminated air (Fig. 2). The level and the distribution of radioactive contamination depends on local conditions, where the strength and direction of the wind plays an important role.

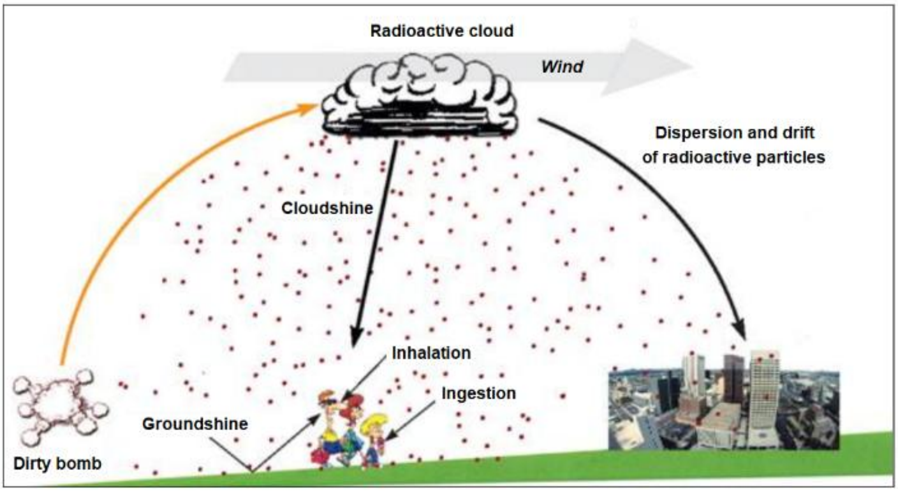


Figure 2 : **Radiation exposure pathways following an attack by a radiological dispersion device**
Source : MEDALIA, J. 2011

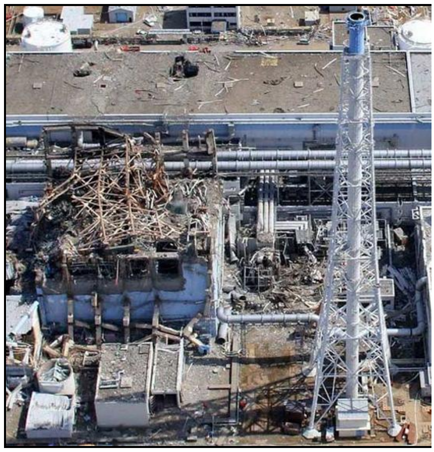
The main approach in fighting radiological terrorism would include strict measures in keeping radioactive sources safe and secured and, as far as possible, to replace or limit radiation and nuclear applications by other methods where possible. However, there are a number of areas (e.g. medicine, non-destructive testing, and production of energy) where in some cases we cannot do without radiation or nuclear technologies. This is why it is so important to increase the protection of these sources against theft and unauthorized access during their production, transport, use, storage and disposal.

It is also important to ensure that the personnel handling radioactive sources is sufficiently qualified not only for work in normal conditions, but also in case of a radioactive or nuclear emergency. Workers are also required to be trained and, in particular, to be familiar with current radiation protection requirements and any accidents that can be foreseen with regard to the focus of the workplace. In addition, radiation workers are required to be able to protect not only themselves but also other workers, including the general public (visits, patients, their escorts, etc.). The exposure of radiation workers shall be regularly monitored in order not to exceed the relevant limit values. The workplace, and possibly its surroundings, should also be monitored for radiation levels and radioactive contamination.

Nuclear accidents, besides exposure due to ionizing radiation emitted by radionuclides released and spread, these also include destructive forces:

- Dangers (human exposure, extensive radioactive contamination on a local and global scale, destruction),
- Nuclear reactors (Sabol, J., Šesták, B. 2017) including nuclear power plants, accidents in Chernobyl and Fukushima (Fig. 3),
- Nuclear reactors used for the production of radionuclides,
- Nuclear research (activation analysis, material properties),
- Nuclear weapons (atomic and hydrogen bombs; loss of bombs during transport).

a)



b)

Figure 3: **The view at damaged nuclear reactors, a) Chernobyl, b) Fukushima**
Source: SABOL,J., ŠESTÁK,B., 2017

As to the assessment of the consequences resulting from the Chernobyl nuclear plant accident, many factors should be considered. One of them is that the accident significantly slowed down the further expansion and development of nuclear energy in many countries throughout the world. In addition, besides the direct damage caused by the accident, the losses included many expenditures such as arrangements to mitigate the consequences within the exclusion zone, social protection and health care to persons affected, research aimed at the health and production of clean food, radiation monitoring of persons and the environment, radiological improvement of settlements and disposal of radioactive waste, resettlement of people and improvement of their living conditions, cost of removing agricultural land and forests from use and the closure of agricultural and industrial facilities, the additional costs of energy related to the damage and eventual closure of the Chernobyl complex and the cancelation of Belarus's nuclear power plant programme (Munro, A. 2011).

It is important to realize that an accident or even a terrorist attack or sabotage at a nuclear power plant cannot be compared with the explosion of a nuclear bomb. It is known that the number of people killed directly during the bombardment at the end of World War II in Hiroshima and in Nagasaki was estimated to be 45,000 and 31,000, respectively. Many people died later; there are some indications that the total number of people killed was more than 140,000 in Hiroshima and about 70,000 in Nagasaki (Ramseger, A. et al. 2009). In Chernobyl there were some 50 victims during the accident or shortly after this event, and it is expected that something like 4,000-5000 affected people may die later of cancer developed as a result of radiation exposure (stochastic effects). On the other hand, there were no immediate deaths attributed to the Fukushima accident but due to the exposure of the vast population on the territory around the site, an additional number of cancer cases (in addition to spontaneous cancer occurrences) are expected during the years following the accident.

When talking about the use of nuclear energy based on the fission of uranium, one has to mention the role of Jáchymov at the very beginning of the atomic age (Sabol, J. 2019).

Some specific economic consequences of radiological terrorist attacks

In general, the use of radiological weapons cannot be excluded and we have to adopt some measures to prevent this from happening and especially to be prepared to deal with such emergency situations in terms of the minimization of the consequences and to return affected sites to normal conditions. One has to be aware that there are many commercially available radioactive sources which can be used for this purpose. However, now we can better estimate the effects of a radiological attack and take into account lessons derived from previous radiation and nuclear accidents, including misconceptions or shortcomings contained in the various attack scenarios.

Principally, one can recognize three main specific components (Bunn, M. 2018) of possible economic impacts typical for industrialized and developed countries (approaching billions of USD) resulting from the use of a radiological weapon (Fig. 4):

- Event recovery costs including survey, decontamination/demolition, disposal, new construction, relocation, compensation, health care,
- Business impacts related to direct impact (losses of GDP from business affected inside the denied area), indirect effects (losses of GDP from business affected outside the denied area), and induced damages (losses of GDP from reduced spending by affected households),
- Perception based impacts, which may persist many years and would concern willingness to purchase goods/services from the affected region, willingness to invest in the region as well as willingness to work in the region.

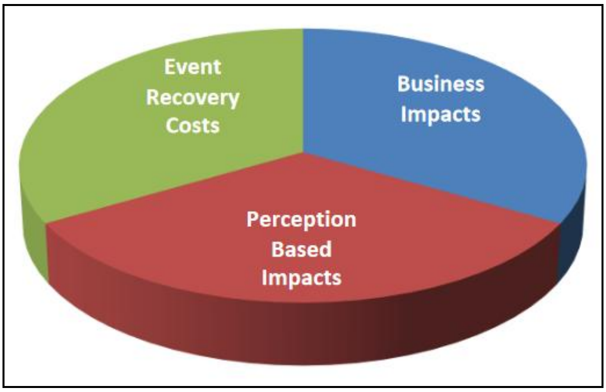


Figure 4: **Three components of economic impacts of a radiological terrorist attack**.

Source: BUNN,M., 2018

The impact of radiological incidents and accidents include the following main cost categories related to response measures, recovery, reconstruction and restoration. Additional 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 an 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. Even a temporary infrastructure breakdown would affect the whole economy.

A dirty bomb explosion has the potential to contaminate the surrounding environment with radioactive substances within a few kilometers. The attack could make contaminated buildings and areas unusable for months to years. This can cause severe disruption of critical infrastructure, force the evacuation of large populations, the cost of lost wages and employment, as well as other negative impacts on business. It will also be necessary to demolish and rebuild contaminated streets and buildings, with a long-term increase in cancer rates. A radiological attack will also cause panic and an atmosphere of fear in the endangered area and its wide surroundings. This is actually what we saw in Goiania following the accident involving strong radioactive sources Cs-137 used for the treatment of cancer patients.

Since radioactive sources used in industry and medicine are used in the construction of a dirty bomb, there are intensive efforts aimed at the replacement or reduction of strong sources in use in many areas. In some cases, however, especially in specific applications of these sources in medicine, we cannot do without ionizing radiation. The only way in these cases is to increase the protection and security of strong sources against theft and unauthorized access (to prevent theft and uncontrolled possession and transport of such sources). The equipment of the workplaces and their use must be at the relevant level in accordance with the national legislation, international standards and decrees as well as instructions from the competent regulatory authorities.

The personnel of the workplaces must be sufficiently qualified not only for work in normal conditions, but also in case of a radioactive or nuclear accident. Workers are also required to be trained and, in particular, be familiar with current radiation protection requirements and any accidents that can be foreseen with regard to the focus of the workplace. Radiation workers are required to be able to protect not only themselves, but also other workers as well as the public (including visitors, patients, their escorts, etc.).

In fighting any kind of terrorism, including radiological terrorism, we have to consider the costs of counter-terrorist measures. Here we have to differentiate between defensive and pro-active security measures. The aim of defensive measures is to protect urban objects from attacks on the one side and to mitigate the potential consequences on the other side. These measures include financial investments in security technologies, surveillance, training etc. Pro-active security measures entail the resources needed to finance intelligence operations, military response, development aid, etc. Undermining the financial resources of terrorist groups is an example of pro-active measures, which are meant to prevent terrorism itself.

Indirect costs of counter-terrorism measures are distributed throughout society as a result of changed economic behaviour of agents (behavioural adjustment) and the impact on functionality of urban objects (e.g. travel delays as a result of security in airports and on roads, changes in property values). A prime example of behavioural adjustment is that protection measures such as barricading, surveillance, security announcements and access-restricting security checkpoints may also enhance fear and anxiety, which can have negative health consequences, and, hence, also create a negative impact on the economy due to changes in economic behaviour.

Recent studies indicate that the make-up of economic consequences of terrorist attacks differs greatly from ordinary events and other types of disasters. The explicit role for resilience, behavioural linkages, remediation, mitigation, interdiction, and macroeconomic interactions should also be considered. The importance of these factors can be illustrated by summarizing the results of recent studies of the 9/11 terrorist attacks. This decomposition facilitates an evaluation of policy options that are most likely to lead to cost-effective reductions in future economic losses from terrorist attacks. An important conclusion of this analysis is that we, rather than the perpetrators, are the major determinant of the consequences of a terrorist attack. After 9/11, our resilience was high, but so was our fear, both of which had profound effects on the bottom line, though in opposite directions. However, subsequent anti-terrorist initiatives were more costly than the direct damage caused by the attack.

The global economic impact of terrorism in 2018 amounted to 33 billion USD, a decline of 38 per cent from its 2017 level. This is the fourth consecutive year that the economic impact of terrorism has declined from the peak of 111 billion USD in 2014. These estimates are considered conservative, as there are many items that are not included in the methodology due to the difficulty in costing them. These include the longer-term economic implications of terrorism such as reduced tourism, business activity, production and investment.

Following the 9/11 attack, the European Union adopted more strict measures in fighting CBRN terrorism, which is considered as a potential threat to the whole region (Sabol, J. et al. 2015). The following figure (Fig. 5) shows trends in the economic impact of terrorism globally from 2000 to 2018. The effect of the September 11, 2001 terrorist attacks is shaded separately in red colour (IEP. 2019).

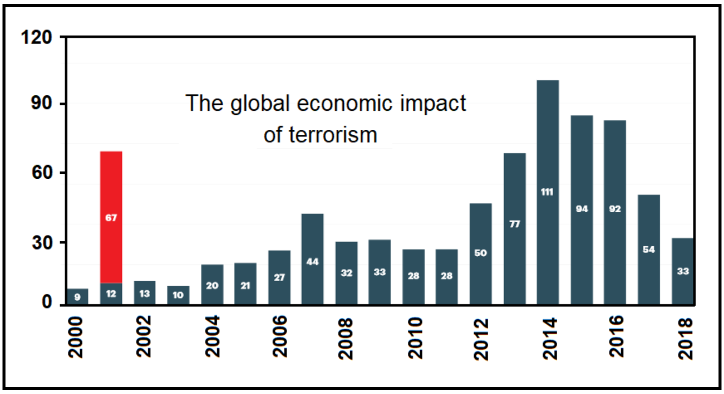


Figure 5: **The economic impact of terrorism in USD billions in years 2000–2018**

Source: SABOL , J. et al., 2015

The economic impact of terrorism model includes the costs from four categories: deaths, injuries, property destruction, and the GDP losses from terrorism. This is related to a large number of indirect costs, which may include the reduction of economic growth, trade, financial markets, tourism, foreign investment as well as deaths and injuries of people affected by the attack.

In adopting efficient steps against terrorism, one cannot overlook the use of some new technologies such as drones, which are capable to deliver a dirty bomb or other CBRN weapons to the target and it would be extremely difficult to prevent such an action when sophisticated drones are used (Sabol, J. 2020). Actually, terrorists have long had an interest in using unmanned aerial vehicles in attacking selected objects, especially those forming critical infrastructure and soft targets. In recent years, the proliferation of cheap, commercially available drones has significantly increased the probability of such attacks causing public disruptions, panic and the spread of fear.

Conclusion

Terrorist attacks lead to billions of USD of economic losses every year. In line with successful efforts to curb and defeat the so-called Islamic State in Syria and Iraq, those losses are now finally gradually slowing down, but it does not mean we have succeeded in overcoming terrorism. The costs reached their peak around 2014, when total global economic damages amounted to 111 billion USD. However, we have to continue fighting international terrorism, where some forms of radiological attacks are expected and one has to be ready for such alternatives.

There have been a number of incidents and accidents involving peaceful uses of radiation and nuclear technologies. The situations and consequences of such events have been widely studied, published and lessons learned. The conclusions from these disasters were instrumental in adopting adequate preventive safety and security measures to avoid such disasters and to minimize their consequences. These emergencies showed us what we can expect when radiological or nuclear terrorist attacks occur.

Currently, all 442 nuclear power reactors worldwide are in operation. They continue to provide 10 percent of the world's electricity and around one-third of its low-carbon electricity. Nuclear power plants can continue operation because of their contingency plans, which include what to do during a global pandemic, such as COVID-19. If there is a concern that not enough staff are fit for duty, nuclear reactors could be pre-emptively shut down and maintained in a stable condition. However, as in the case of all CBRN components, COVID-19 has to be considered as another biological dangerous agent, the spread of which may be assumed as something a terrorist could deliberately utilize in future attacks.

Sometime, the cost estimation reflecting the impact of terrorist activities does not take into account the losses from counterterrorism or countering violent extremism, nor the impact of diverting public resources to security expenditures and away from other government activities. It does not calculate any of the longer-term economic implications of terrorism from reduced tourism, business activities, production and investment. As a result, the economic impact of terrorism represents a conservative estimate.

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