Science and Technology Trends
Safety Research and Risk Management Policy in Asia

Science and Technology Policy for Social Safety in Japan

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1. A Brief History of the Research on Safety in Japan

In Japan, most of the science and technology research activities for social safety were promoted through safety engineering. However, conventional safety engineering only focused on safety in a restricted environment such as industrial safety or occupational safety in a factory. These lacked a comprehensive perspective on the safety of scientific/technological systems in the social environment where common people live in.

However, there are many trials going on currently that complement the safety of science and technology in the society, or the role of science and technology for the safety of society. These trials were driven by significant disasters, incidents, and accidents that have occurred.

1.1 The Great Kanto Earthquake

Japan is a country of volcanic islands, which often suffers from repeated earthquakes, and is susceptible to massive ones. The Noubi Earthquake that occurred in Gifu prefecture in October 1891 recorded at magnitude 8.0 and caused more than 7,200 deaths. As a response, the Japanese government established the "Investigation Committee on Prevention of Earthquake Disasters" in 1892.

Akitsune Imamura, a famous seismologist, contributed an article to a general interest magazine that subsequently drew a strong public reaction. In the article, he predicted the possibility of a huge earthquake in Kanto area in the coming 50 years and recommended that the people prepare for the impending disaster. Other seismologists criticized him for carelessly deluding the people.

However, as Imamura predicted, the Great Kanto Earthquake actually struck the Kanto area, which was centered in Tokyo and Kanagawa prefectures, on September 1, 1923. This 7.9-magnitude earthquake left more than 100,000 people missing and dead. Even though the committee made intensive researches on the aftermath of the earthquake, it was dismantled in 1925 because it was unable to make practical contributions for the prevention of earthquake-related disasters. Eventually, the committee's task was down-scaled and was taken over by a new council. And these changes led to the establishment of the Earthquake Research Institute of the University of Tokyo.

Within the history of Japan, the Great Kanto Earthquake disaster was the one that had dealt a huge damage to the society. It subsequently formed

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the basis of Japan's disaster prevention measures. September 1 became the "National Disaster Prevention Day" and every year, disaster drills are conducted throughout Japan, which still persists today. Currently, the "Central Disaster Management Council"—consisting of the prime minister as the chairman, all cabinet members, presidents of public institutions, and academic experts—controls the Japanese disaster prevention measures, including the one for earthquakes. Its expert panels conduct investigations on earthquakes and damage estimations.

However, as Figure 1-1, 1-2 and 1-3 shows, appropriate disaster prevention measures vary by each earthquake. This is the reason why the importance of a comprehensive disaster prevention measure is better emphasized compared with the measures taken only from the science and technology field.

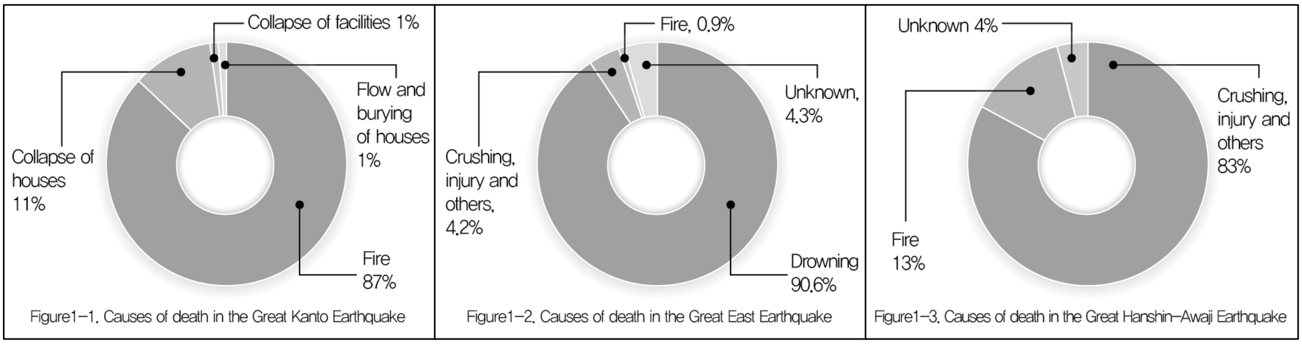

Figure 1-1, 1-2, 1-3 Causes of death of the three biggest earthquakes in Japan

Source: Fire and Disaster Management Agency. "東日本大震災記録集" (Records of the Great East Japan Earthquake). March 2013. (Original source data are the following: Figure 1-1, Takafumi Moroi and Masayuki Takemura. "Mortality Estimation by Causes of Death Due to the 1923 Kanto Earthquake". Journal of Japan Association for Earthquake Engineering Vol.4. No.4. September 2004.; Figure 1-2, released data from the National Police Agency, September 2012.; Figure 1-3, released data from the office of the medical examiner of Hyogo prefecture, 1995.)

Thus, in past massive earthquake disasters, though seismological measures or comprehensive disaster prevention was highly emphasized, the entire frame of science and technology could not be revised. This could be because the science and technology community was not broad enough, or because of the sense of distance between science and technology and the people's daily life at the time.

1.2 The Concept of Safety and Security

It is actually recent that the science and technology community in Japan began to examine the role of science and technology against disasters and accidents in the social environment.

In the late 1990s, significant incidents and accidents in nuclear facilities consecutively occurred.

In December 1995, the metal sodium that leaked from a secondary coolant system of a prototype fast breeder reactor, "Monju," caused a fire in Tsuruga City, Fukui prefecture. This incident was classified as level 1 (anomaly) according to the International Nuclear Event Scale (INES).

In March 1997, a fire explosion occurred during the process of asphalt solidification of low-level radioactive waste liquid in the Tokai reprocessing plant of the Power Reactor and Nuclear Fuel Development Corporation (PNC) in Tokai village, Ibaraki prefecture. The explosion was caused by heat from a chemical reaction. It was classified as level 3 (serious incident) according to the INES, though no one was injured.

In September 1999, JCO Co., Ltd., a nuclear fuel conversion company, caused a uranium criticality accident by using an informal manual. Three staff members were exposed to a huge amount of neutrons, and two of them died. This accident was classified as level 4 (accident with local consequences) according to the INES.

These incidents and accidents brought up the issue of the society's distrust in the safety of science and technology among the scientists. Successive crises gave the opportunity for scientists to conduct a review of the science and technology policy.

The Science Council of Japan (SCJ), which represents the Japanese scientist community, had been discussing social safety from the end of the 1990s, and two reports had been released in 2000 (SCJ, 2000a) (SCJ, 2000b).

The report "Toward establishing safety studies" (SCJ, 2000a) released by a SCJ task force on safety targets accidents that are caused by an artificial object and are related to the usage of products and services. It classifies accident sources and then indicates the required elements to ensure security: (1) to have management executives recognize safety management as an important issue of the management and put safety managers in leadership positions where they can perform their duty; (2) to place emphasis of technology development on maintenance and repair technology in the governmental budget administration system; (3) to build a database of various accidents and to establish a permanent organization which delivers the information; (4) to establish an accident investigation system; (5) to cultivate engineers' ethics as professionals; (6) to reconsider the regulatory administration system with taking in the modality of self-regulation; (7) to abandon an absolute safety and switch to an evaluation of safety by risk; and (8) to enhance the education on safety and ethics in higher education institutions.

Yoichiro Murakami, who is a well-known researcher on the history and philosophy of science, proposed the concept of "safety studies" (安全学) and made this term known by people in Japan. As can be seen from the fact that the concept of safety studies was explained in a series of articles on the monthly magazine titled "Contemporary Philosophy" (現代思想), it considers safety from an interdisciplinary point of view. The report seemingly aimed to construct an integrated study on safety as it used the term "safety studies" instead of "safety engineering."

2. After the Great East Japan Earthquake and the Fukushima Daiichi NPP Accident

It was also a nuclear accident that drove the science community to conduct again a review, from the perspective of safety and security.

In March 2011, the strongest earthquake in Japan was recorded at magnitude 9.0, which occurred from off the coast of Miyagi prefecture. It caused a massive tidal wave (*tsunami*) of 40.5 meters high at most on the Pacific coast of eastern Japan. It inflicted great damage and left more than 18,500 of the population missing and dead. Moreover, this tsunami also hit the Fukushima Daiichi Nuclear Power Plant (FDNPP), which is located on the Pacific coast.

At the time of the earthquake, the inserted control rods halted the nuclear reactors. However, the earthquake cut an electric power cable from outside, and the tsunami also destroyed an emergency power source. Cut-off with electricity, the power plant was thus unable to cool down the reactors. It resulted in a major nuclear accident with a mass radioactive substance release. The INES level was 7 (major accident), which is the maximum, and stands at the same level with the Chernobyl nuclear reactor accident.

Soon after the earthquake, the plants of FDNPP actually exploded one after another despite the words from "specialists on nuclear power" in the mass media that the situation of the reactors seems to be noncritical. The explosion was even witnessed by the people on TV. A nuclear power plant, which is thought to be a crystallization of the high-end science and technology of human beings, easily went out of control because of the "unexpected" level of tsunami. The "myth of safety" was broken down, causing science and technology to deeply lose the trust of the people.

According to the survey by the National Institute of Science and Technology Policy (NISTEP) in November 2010, which was months before the earthquake occurred, the question "Do you think the stories of scientists are trustable?" was answered positively by 83.3% of the people (15.8% answered "trustable" and 67.5% answered "relatively trustable"). However, the number dropped to 68.2% (6.5% answered "trustable" and 61.7% answered "relatively trustable") in May 2011 after the earthquake. (Figure 2-1, 2-2.)

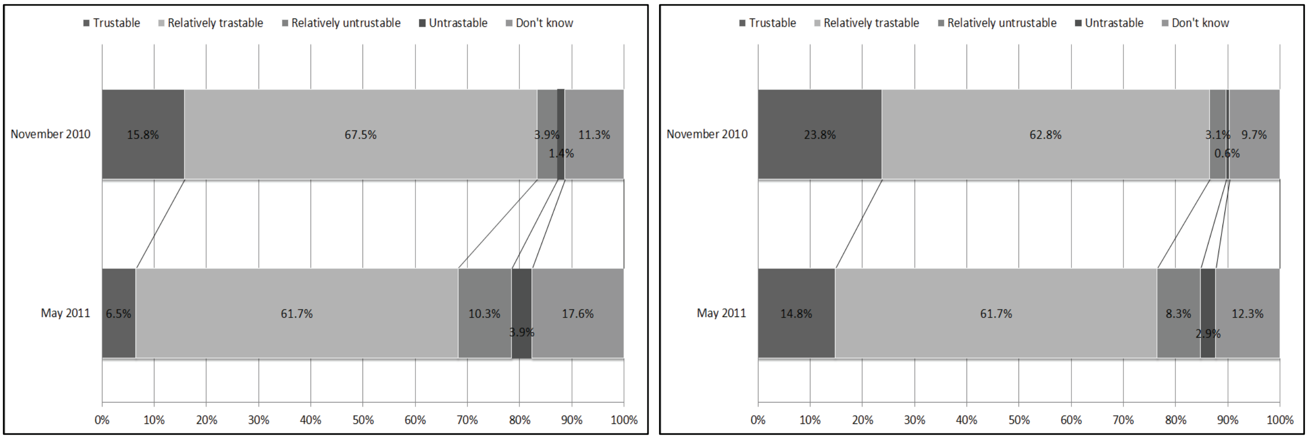

Figure 2-1, 2-2 Graphs of answers to the question "Do you think the stories of scientists/engineers are trustable?"
Source: National Institute of Science and Technology Policy (NISTEP). http://www.nistep.go.jp/wp/wp-content/uploads/12gatu-made_shinraido.pdf.

Unlike past responses to disasters, the scientific community shared the same sense of crisis.

The 4th Basic Program for Science and Technology (CSTP, 2011), which was supposed to start from April 2011, was postponed in response to the earthquake and the nuclear accident. They reconsidered the program to redeem the understanding, trust, and support of the people for science and technology.

A report of one of the subcommittees of the Ministry of Education, Culture, Sports, Science and Technology (MEXT, 2011) pointed out that a timely and appropriate publicity activity, i.e., "risk communication," is important.

The feeling of "security" is the opposite of "anxiety". Thus, the resolution of anxiety would lead to security. However, it is very difficult to bring back the feeling of security, even with scientific reasons, if the people had felt anxious even once. Social anxiety is a significant factor in the construction of a "culture of security." It is very difficult to resolve this underlying anxiety though. People would at least have to understand and construe scientific and objective facts to resolve it. Therefore, dialogues to enrich the understanding of the people by accurately and carefully conveying such facts in simple, understandable words (risk communication), is needed to make "security" take root among people.

The cabinet of Japan decided the 4th Basic Program for Science and Technology in August 2011. In the program, the science and technology innovation policy was set to be a part of the "policy for the society and the public." In this manner, to deepen the relationship between the society and science and technology innovation, popular participation in the policy process, enhancement of science communication including risk communication, and other related matters were included in the program.

After that, a MEXT study group reported "The Promotion Strategy of Risk Communication" in March 2014 (MEXT, 2014a). In the report, the approaches and issues of risk communication done in Japan were organized as seen in Figure 3.

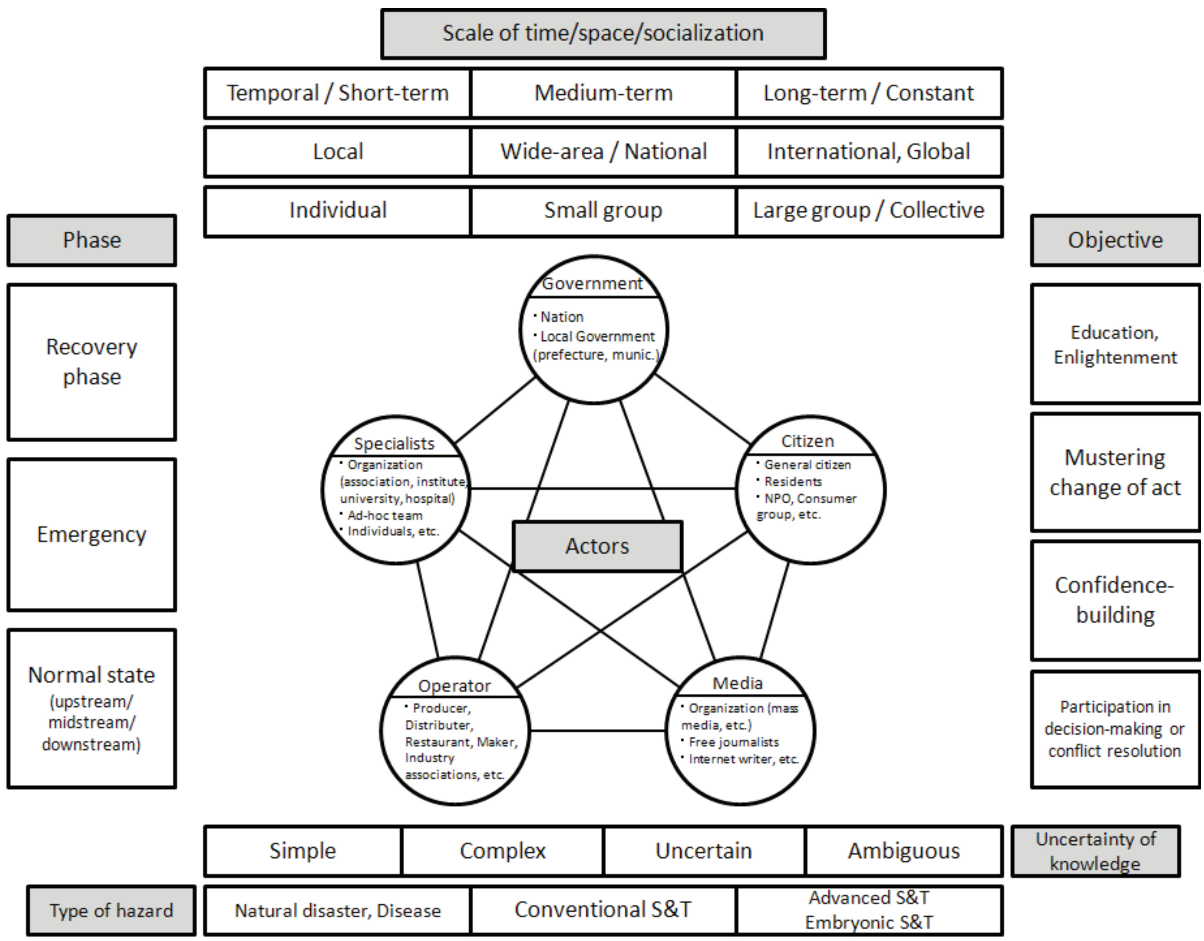

Figure 3 Types and framework of risk communication

Source: The Promotion Strategy of Risk Communication (MEXT, 2014a)

It focuses on risk communication during a normal state, instead of crisis communication, and also pointed out the following objectives: (1) to develop basic literacy of risk communication for all stakeholders; (2) to provide opportunities of risk communication for stakeholders where they can subjectively participate for seeking solutions to the problem; (3) to store the experiences and knowledge of good practices of risk communication in a long term in order to establish risk communication activities as a social culture; (4) to cultivate people who will assume coordination and mediation between the stakeholders in various fields; and (5) to have all the stakeholders learn risk-related science and technology literacy. The report said that these are needed and had provided some practical approaches.

3. Transition of the Concept of Safety in Japan

3.1 Safety and Security

From around 2000, a set of keywords "safety (*anzen*) and security (*anshin*)" came to appear often in the field of Japanese governmental policy. There is actually no English word that would stand for the Japanese word "anshin," which means "peace of mind based on a sense of safety." For our purposes, this word would be translated as "security." Security is important for people but security should be premised on safety. With this, these two concepts are thus required at the same time.

The 2nd Basic Program for Science and Technology was decided in March 2001 (CSTP, 2001). It had set "a country where people can enjoy safe secure high-quality life (realization of affluent society by intelligence)," as one of the three national goals.

To be more precise, some technologies were thusly targeted: disease gene mapping and the formation of a scientific/technological basis to realize a personalized medicine that is based on the genetic map; the minimization of damages from natural disasters such as earthquakes or typhoons; the stable provision of quality foods using biotechnology; and risk reduction of science and technology.

Subsequently, MEXT launched an advisory panel on science and technology policy for a safe and secure society. The panel compiled a report in April 2004 (MEXT, 2004).

3.2 Definition (Concept of Risk)

The reports defined safety and security, which can be seen in the following.

The Role of Safety Engineering for the Social Safety (SCJ, 2000b)

- *Safety: A state wherein the peace of both mind and body are not detracted; a state wherein one's own properties are not detracted or deflected in value.*

- *Security: A subjective feeling that is related to safety and used in two ways. One is a state wherein safety is ensured and there would be no expected human/economic damage, or a state wherein damage could exist but would be covered by medical service or insurance, and is sure to return to an initial state. In such cases, such state is called "secure." The other is a state wherein there will be no damage on others caused by one's fault, or even if there were damage on others, it is supposed to be covered by medical service or insurance.*

The Report from the Advisory Panel for Science and Technology Policy for Construction of the Safe and Secure Society (MEXT, 2004)

- *Safety: Being objectively judged that there would be no damage on humans and the community, or on properties owned by the person, an organization, or the public. The term "property" here includes intangible assets.*

- *Security: The meaning of security depends largely on a subjective consideration of each person. In this advisory panel, some definitions of security were provided such as "a belief that the things would not be so much different from what people* *expect through their knowledge and experience," or "a belief that anything unexpected would not happen or that even if something would happen, it should be acceptable."*

With these definitions, we can see that they defined safety as something objective and security as something subjective. In contrast to these definitions, SCJ (2005) introduced a definition of safety from the ISO/IEC Guide 51, which uses a concept of risk. The definition in JIS (Japan Industrial Standards) Z 8051 is the same as with the one on ISO/IEC.

- *Safety: freedom from risk which is not tolerable*
- *Risk: combination of the probability of occurrence of harm and the severity of that harm*
- *Harm: injury or damage to the health of people, or damage to property or the environment*
- *Tolerable risk: level of risk that is accepted in a given context based on the current values of society*

By using the concept of risk, not abstract safety, the scope of the issues was removed from the field of philosophy. It means that it moved from a field of rights and conflicts of acceptable values, to the field of science and mathematics. In fact, reports of SCJ in 2000 (SCJ, 2000a) (SCJ, 2000b) already pointed out that we should change the recognition of safety from "absolute safety" to "evaluation of safety rated by risk." However, it took a long time to be widely used in science and technology policy.

Incidentally, the Economic and Social Research Institute of the Cabinet Office (ESRI) has been conducting researches on disaster risk management and economic policy from the viewpoint of risk financing in economics.

4. Recent Studies and Policy Trends

4.1 Safety Goals of Technological Systems

A SCJ subcommittee recently compiled a landmark report named "Social Safety Goals of Technological Systems" in September 2014 (SCJ, 2014). In this report, based on the recognition that a safety goal varies across the ages, it shows a practical shape of safety goals that should be accomplished in the technological systems of modern society, as well as a basic guideline to accomplish this goal. Moreover, it shows a practical study on the safety of eight technological systems, for example, nuclear power systems, chemical plant systems, information systems, and traffic systems.

In the report, it divides the problems of safety goals into categories: (1) goals targeting human life and (2) goals targeting social risk. For the goals targeting human life, they set two criteria values, which are A and B. Criterion value A is the minimum requirement for the risk of technological systems that should be accomplished no matter how beneficial the system is for the society. Criterion value B is the sufficient value of risk without any conditions where no additional improvement is required. For a technical system that would affect an unspecified individual, it says that it is preferable to set the criterion value A at around 10^{-3}–10^{-4} / year at most. For the criterion value B, it requires to keep it to less than 10^{-5}–10^{-6} / lifetime as an immediate goal.

How then should these criteria values be estimated? There are some rough estimations of the orders of the criteria values A and B on the report. First, it makes an important provision that without any conditions most people may accept an increase of risk at 0.1%, compared to the natural risk that people are generally exposed to. This shall be called tolerable risk increase. This tolerable risk increase is derived from a description in the U.S. Nuclear Regulatory Commission (NRC)'s policy statement "Safety Goals for the Operations of Nuclear Power Plants" released in 1986 (NRC, 1986) —*"The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed."*

With regard to the value A, (1) the UK Health and Safety Executive (HSE) sets an acceptable maximum of fatal occupational injuries at 10-3/year. In a lifetime, it will be 10^{-3}×1,800 working hour/year ×70 years/lifetime/(24×365 hours/year) = 1.4 × 10^{-2}/lifetime. (2) At the same time, the death rate within a lifetime is 1/lifetime, thus A would be 10^{-3}/lifetime, based on the provision of the tolerable risk increase.

With regard to the value B, (1) the minimum average death rate in the national population survey report of Japan in 2010 is 7.1 out of 100,000 people a year for women from the age of 10 to 14 (7.1×10^{-5}/year). (2) HSE sets the broadly acceptable rate of fatal occupational injuries as 10^{-6} per year. In a lifetime, it is 10^{-6}×1,800 working hours/year×70 years /lifetime/(24×365 hours/year)=1.4×10^{-5}/lifetime.

The report also provides example ideas of safety goal for some types of risk. If there is a threshold for the appearance of influences in a system, 0/lifetime can be achieved by keeping the risk lower than the threshold, or by accomplishing the value B. If there exists a cost for reducing the hazard, the application of the system should be decided based on the ALARP (As Low as Reasonably Practicable) rule to reduce the DF (Disproportion Factor), which is a ratio of cost against the reduced risk (Figure 4).

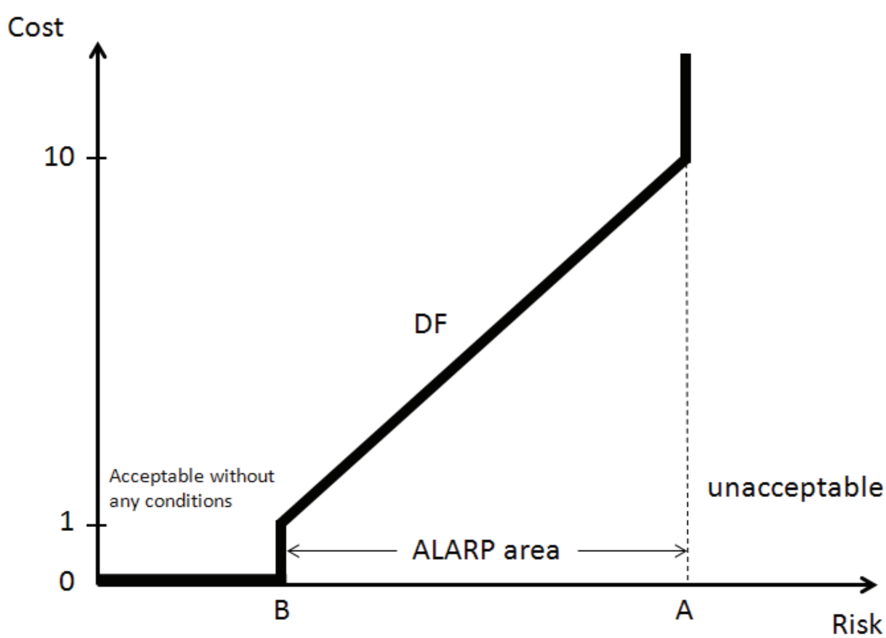

Figure 4 Disproportion Factor

Source: Social Safety Goals of Technological Systems (SCJ, 2014)

Figure 5 shows a relation between risk and cost to reduce risk. Supposing that the optimum solution is where the sum of the risk and the cost is the least (DF=1), the accomplishing risk is 1. If an investor puts 10 times of the cost compared to the risk (DF=10), the accomplishing risk is 3. If this risk is larger than the value, the system should be abandoned. In case the system is unavoidably necessary, more cost to achieve value A should be placed. (It is also possible to deduct the benefit from the risk.)

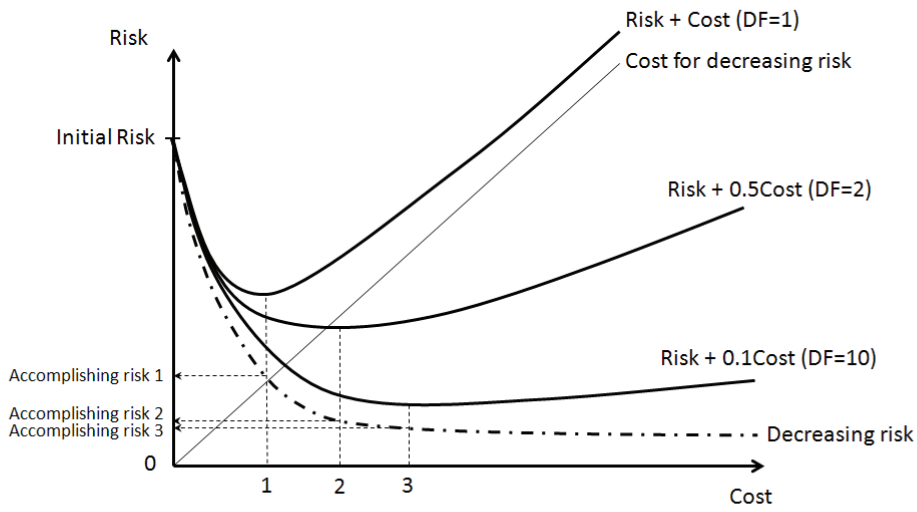

Figure 5 Risk vs. Cost

Source: Social Safety Goals of Technological Systems (SCJ, 2014)

4.2 Policy Trends and Target-oriented Research Activities

"The Action Plan for the Important Science and Technology Issues, 2014" (CSTP, 2013), which defines the focusing areas of Japanese science and technology policy, shows some researching topics related to the safety and security of the society. Some projects are classified in the section of "Ensuring safety and security of Infrastructure" and "Enforcement of resilient function of disaster prevention and reduction," for example: non-destructive inspection of buildings with the use of high-frequency radio wave and neutrons; robotics technology for infrastructure inspection; durability enhancement of social infrastructure; E-Defense (3-D Full-Scale Earthquake Testing Facility); developing researching center for structural materials; ALOS-2 (Advanced Land Observing Satellite-2); GOSAT-2 (Greenhouse gases Observing SATellite-2); GCOM-C (Global Change Observation Mission-Climate Satellite); size reduction of SAR (Synthetic Aperture Eadar) and SAR aircraft for information gathering; and prediction technology of regional extreme weathers.

Thus, actual activities of science and technology development for the social safety are scattered over many scientific policy fields. It is because there are currently no "comprehensive" policy packages for the safety of the society in Japan. Moreover, it is not a single technology that realizes the safety and security of the people's lives. The technology consists of many element technologies over many sectors. This means that the development of safety technology realized by each single would be limited. This is one of the problems in promoting science and technology for safety.

Conventionally, the Japanese science and technology policy mainly consisted of two sides of the approach, i.e., a bottom-up approach that is based on free ideas of researchers in basic research field, and a top-down approach as national projects in applied research field.

In contrast, the recent Japanese science and technology policy tends to introduce a mission-oriented method that is similar to DARPA's end-game approach. Here, a funding agency sets a high-risk strategic target and a Project Manager (PM) chooses element technologies to realize the target technology from any field, including basic science.

This method conforms to a recent Japanese research and development trend that aims to solve specific policy issues. Moreover, a MEXT task force proposed that they should promote mission-oriented researches even in high-risk basic science ("use-inspired basic research" of the quadrant model by Stokes) in June 2014 (MEXT, 2014b) (Figure 6).

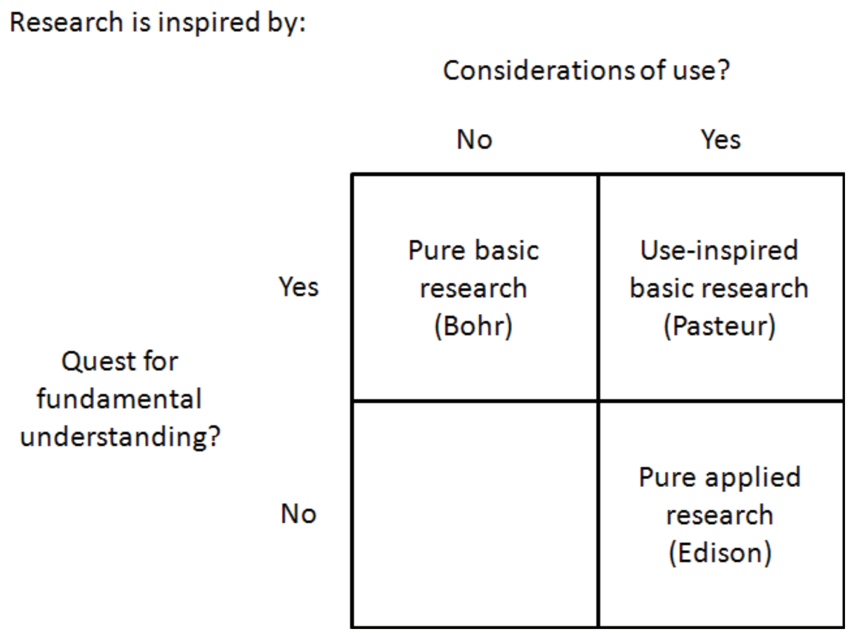

Figure 6 Quadrant Model of Scientific Research

Source: Stokes, Donald E. (1997). "Pasteur's Quadrant: Basic Science and Technological Innovation". Brookings Institution Press.

Seeing these trends from the standpoint of safety and security, for example, the report of the subcommittee of MEXT (MEXT, 2011), it classifies the threatening factors on safety and security as crime, accident, natural disaster, war, cyberspace problem, health problem, social life problem, economic problem, political and administrative problem, environment and energy problem, and other complex problems. Also, it proposes a research project that tackles these potential risks. The Japan Science and Technology Agency (JST) also proposed to position science and technology for social security as one of the important pillars of science and technology innovation policy, as well as to launch an open-type research program for social security (JST, 2012).

JST already started a research program for the practical utilization of counter crime/terrorism technology for a safe and secure society. The program proceeded as an integration of the mission definition based on real needs of practical field sites, research development, and demonstration under the cooperation of related ministries from 2010. The program is developing technologies and systems such as chemical/explosive/nuclear material detecting technology, human recognition system, and positive pressure personnel suit (Table 7).

Table 7 Adopted projects of the JST's program for the practical utilization of counter crime/terrorism technology for a safe and secure society

Project Title	Main Promoting Agency	Fiscal Year of Start	Fiscal Year of End
Criminal Investigation System by Personal Image Analysis (Development of Personal Image Analysis System)	Osaka University	2010	2014
Automatic Sampling Trace Detector System (Development of Explode/Hazardous Material Detector)	Hitachi, Ltd.	2010	2014
Development of On-site Mass Spectrometer for the Drug Detection (Development of Portable Illegal Drug Detector)	National Research Institute of Police Science	2010	2014
Development and Utilization of Millimeter-wave Passive Imaging Device (Development of Explode/Hazardous Material Detector)	Tohoku University	2010	2014
Development of Comprehensive and Immediate Detection System for Chemical Agents (Development of On-site Detection System for Chemical Agents)	National Research Institute of Police Science	2010	2014
Non-destructive Nuclear Material Detection System using Gamma-ray (Development of Nuclear Material Detector)	Kyoto University	2010	2014
Environment Adaptable and Practical Person Identification System (Development of Personal Image Analysis System)	OMRON Social Solutions Co., Ltd.	2010	2014
Remote Detection by Electronically Tuned Mid-Infrared Laser (Development of Remote Detection System for Chemical Agents)	RIKEN	2010	2014
Lightening of Positive Pressure Biochemical Suit (Improvement of Biochemical Suit)	Shigematsu Works Co., Ltd.	2010	2014
Development of Spectrum Imaging Device for Criminal Investigation Assistance	Waseda University	2011	2015
Development of Portable Bio-sensor for Biological/Chemical Agents	Osaka University	2011	2015

5. Conclusions

Though the Japanese study on safety took a long path including some nuclear accidents, it is now working on the design of technological systems that can accomplish safety goals based on the concept of risk. According the report, the safety goals of the huge technological systems targeting human life should be at around 10^{-3}–10^{-4} /year at most, and the sufficient goals where no additional improvement is required should be kept to less than 10^{-5}–10^{-6} /lifetime as an immediate goal in terms of risk.

With regard to actual technologies that ensure the safety of technological systems, it seems that the mission-oriented method is suitable as the element technologies are spread over many sectors. Therefore, it is likely that even in the area of "use-inspired basic research" of the quadrant model, a strategic target related to safety will be established. With this, it should accomplish epoch-making technologies for safety of the society.

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