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Systems Pathology of Social Organizations: Fukushima Nuclear Catastrophe 3.11

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Abstract

The magnitude 9.0 earthquake and tsunami that struck northeast Japan on March 11, 2011, were unavoidable natural disasters, but we consider the subsequent breakdown of the Fukushima nuclear power plants to be a catastrophe created by avoidable human errors – an organizational disaster. We review the mistakes that have led up to the present nuclear crisis, and recommend several steps to avoid similar crises in the future. These include issues of (i) determining whether the Fukushima catastrophe was an accident or a man-made disaster? (ii) irrational decision-making due to the pathology of Japanese organizations, (iii) the business ethics of power companies running 40+ years old ageing nuclear reactors, (iv) tired management and system fatigue that administrated the hidden trouble of old reactors as social responsibility, (v) dynamics of systems pathology caused by non-rational governance or multi-system errors of disclosure for stricken area and overseas, (vi) un-homeostasis means the pathology or apoptosis that is 'Fukushima Formula' applying to the nuclear reactor in the world.

Key words: socio-cybernetics, business ethics, social responsibility, governance, un-homeostasis

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I. Is the Fukushima Nuclear Catastrophe an Accident or a Man-made Disaster?

The earthquake and tsunami that struck northeast Japan on March 11 of this year were natural disasters of unprecedented scale. More than 24,000 people lost their lives; about 100,000 people have evacuated the area; more than 250 billion dollars of damage was done; and it is expected that rebuilding the homes, businesses and infrastructure of a large section of Japan will take more than 30 years. While most of the time, energy and money should now be devoted to reconstruction, there are fundamental questions with regard to the failure of the nuclear power plants that demand to be answered. The starting point of our research is the question: Was the yet-unresolved Fukushima nuclear power plant accident an unfortunate natural disaster or an avoidable organizational catastrophe? For the reasons explained below, we conclude that it was a man-made ***catastrophe*** (as defined by Thom, 1977). The origins of the Fukushima nuclear problem lie in system pathology.

II. Irrational Decision-Making to Locate in a Quake-Prone and Tsunami Area

The primary and fatal errors that led to the Fukushima disaster were made already in the late 1960s and early 1970s when the construction of multiple nuclear power plants on the northeast shoreline of Japan was approved. It is of course well-known that earthquake tremors are frequently felt in nearly all corners of Japan, but the historical record is unambiguous in indicating that the Tohoku Region has experienced the most frequent and most severe earthquakes in Japan, and is a region where catastrophic tsunamis have wiped out coastal towns and villages within recorded history. Magnitude 7~8 earthquakes have frequently occurred in the Tohoku region and the largest earthquake in Japan occurred in the same region about 1000 years ago, the so-called Jogan earthquake. It is consequently beyond understanding that specifically the shoreline of the Tohoku area would be chosen as the location for nuclear facilities.

As shown in Figure 1, the Fukushima nuclear power plants were set up in an area of highest earthquake probability in Japan. Furthermore, over the course of 40 years, there were fully 120 disclosed problems at these power plants, and a still-uncertain number of undisclosed problems.

The relative proximity of the Tohoku region to the industry-dense, power-hungry regions of metropolitan Tokyo was of course a prime factor in the selection of sites for power plants. The low cost of rural land, the likely economic benefits of building large facilities in the Tohoku region and the absence of an effective, populist opposition to the construction of nuclear power stations were also relevant factors. But, what the power companies and politicians could not provide on their own was a convincing argument concerning the safety of the facilities. For that reason, they needed to

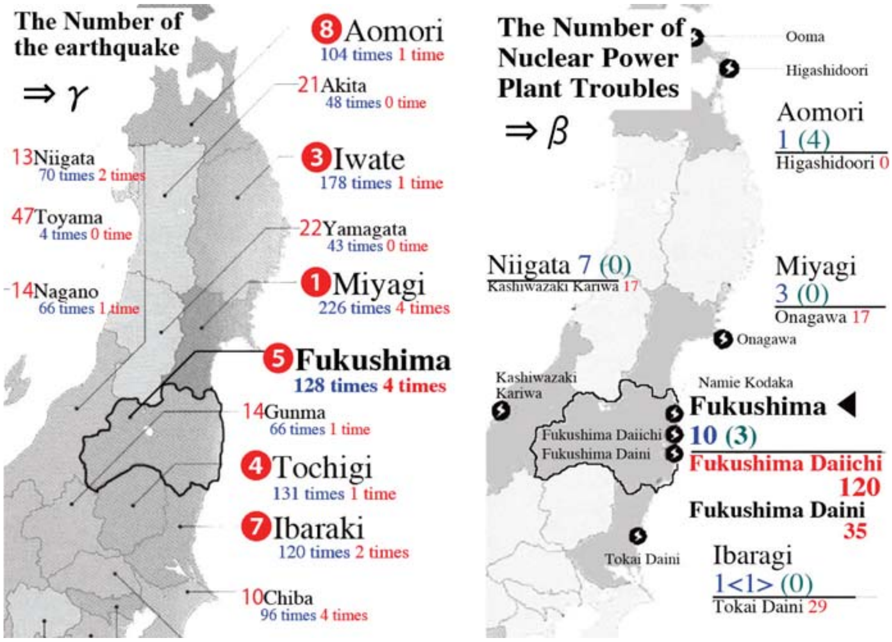


Figure 1 On the left is shown the incidence of earthquakes in the Tohoku Region (from 2008.9 to 2009.8). The number of earthquakes is shown below each location, followed by the number of earthquakes of seismic intensity more than 4. On the right is shown the number of operating (planned in parentheses) nuclear reactors, followed by the number of nuclear power plant troubles (source: Masai, 2009, p.93, p.105).

solicit the advice of geologists and nuclear physicists for objective, disinterested, scholarly approval of the construction plans.

In fact, there was an abundance of academics willing to approve the plans of the power companies for paltry sums. Some of the scholarly advisors have belatedly come forth with their apologies and "*mea culpa*" rationalizations, but the bottom-line is that they were rewarded for agreeing with the power companies that inordinate safety risks were not being taken in constructing those nuclear facilities – facilities essentially at sea-level in one of the most earthquake-prone and tsunami-prone regions in the world. One such advisor has recently confessed that his advisory fee over a period of years was 936,000 yen ($11,700 in US dollars) per month, regardless of the frequency of the actual meeting of the advisory committees (Aera, May, 2011). It is difficult to decide which is the greater crime: the continued operation of trouble-prone, ageing nuclear reactors by the power companies, the absence of independent government oversight of the power plants or the willingness of academic yes-men and lackeys to approve the construction and continued operation of power plants well beyond their period of trouble-free operation.

The response of the Tokyo Electric Power Company and the government to the nuclear power plant disaster has clearly not been sufficient. The disclosure of ambiguous, contradictory and incomplete information has only added to the fear and suffering of the victims. We have calculated the total milliSievert exposure over the first 3000 hours since the tsunami. Figure 2 shows that the radial distance from a nuclear power plant is an unreliable measure of the danger zone. Outside the area of evacuation that the government has established, radiation doses much above normal have been recorded, for example, in Koriyama and Tenei. Notably, measurements at prefectural schools indicate that five places exceed the provisional standard value that the government established – 3.8 micro-sieverts – and there are many points where doses of radiation of 2–3 micro-sieverts per hour have been detected. The Government decided on a provisional radiation standard for schoolyards of “20 milli-Sieverts per year”. That standard was based on the ICRP’s recommendation for adults, but can it be applied to children, as well? A special advisor to the Cabinet’s nuclear engineering specialists noted the danger, and subsequently resigned. Nevertheless, the schools located outside the evacuation zone in Fukushima Prefecture continue to carry out classes as usual. Clearly, it is necessary to disclose information, not only for the needs of governmental administration, but also for the needs of residents in areas affected by natural disasters.

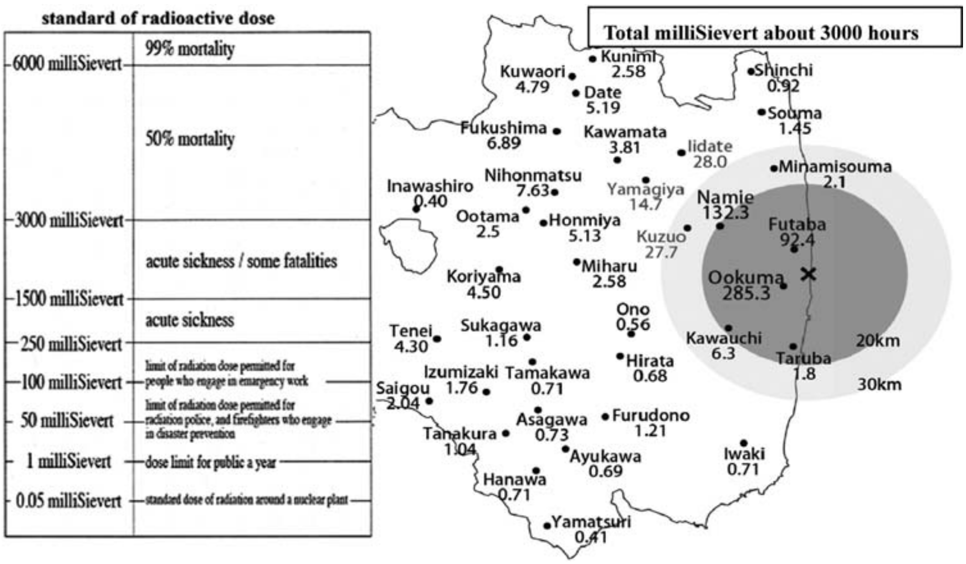


Figure 2 On the left is shown damage due to radiation exposure. On the right is shown the geographical distribution of radiation around Fukushima reactors since March 11.

III. Business Ethics; Operating the Ageing Nuclear Systems

The Fukushima Daiichi Nuclear Power Station includes 6 nuclear reactors, all of which are more than 30 years old (Table 1) and all of which were initially scheduled to be decommissioned at 30 − 40 years.

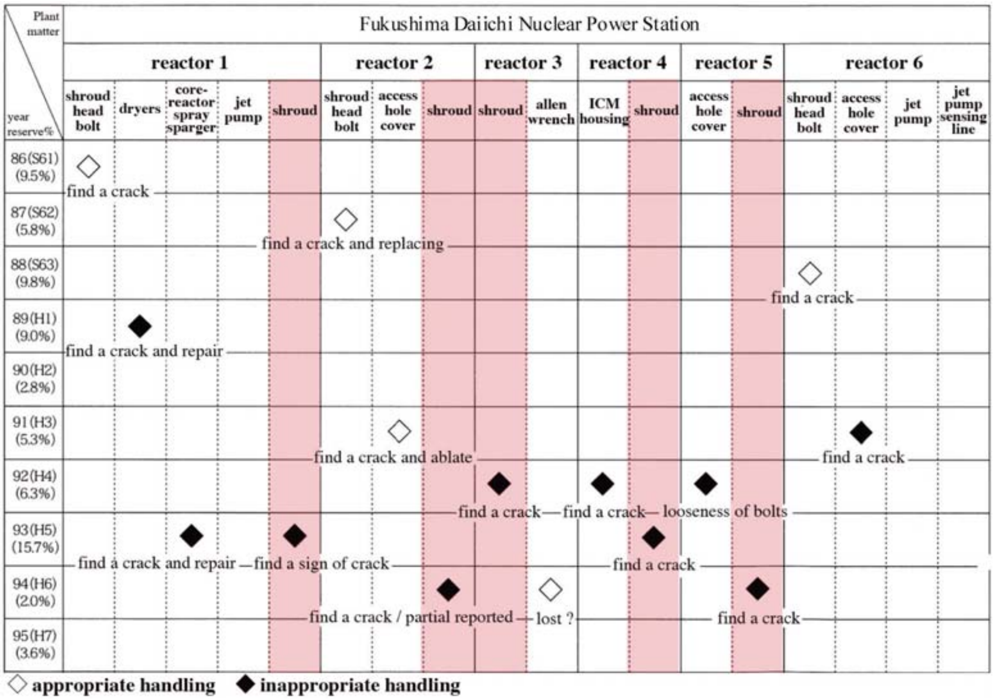
Table 1 Ageing of Nuclear Reactors in Japan (Source: Masai Y., 2009, p.93).⇒α

Nuclear Power Plant Name	Period of Operation	Latest Permission
Tsuruga (West) reactor 1	**41 years** and 2 months	○
Mihama (East) reactor 1	**40 years** and 6 months	○
Fukushima Daiichi (East) reactor 1	**40 years** and 2 months	○
Mihama (West) reactor 2	**38 years** and 10 months	○
Shimane (West) reactor 1	**36 years** and 2 months	○
Fukushima Daiichi (East) reactor 2	**36 years** and 10 months	○
Takahama (West) reactor 1	**36 years** and 6 months	○
Genkai (West) reactor 1	**35 years** and 7 months	○
Takahama (West) reactor 2	**35 years** and 6 months	○
Fukushima Daiichi (East) reactor 3	**35 years** and 2 months	○
Mihama (West) reactor 3	**34 years** and 5 months	○
Igata (West) reactor 1	**33 years** and 8 months	○
Fukushima Daiichi (East) reactor 5	**33 years** and 1 month	○
Fukushima Daiichi (East) reactor 4	**32 years** and 7 months	○
Fukushima Daiichi (East) reactor 6	**31 years** and 7 months	○

To begin with, the life of nuclear reactors is not specified by law. Even if a nuclear reactor is found to be ageing, power companies can operate it semi-permanently, provided that it passes the maintenance inspection every decade. Specifically with regard to the Fukushima Daiichi power plant's reactor No.1, the Nuclear Industry Safety Agency permitted its operation for more than 40 years on February 7, 2011 (NISA, 2011, p.2). These nuclear reactors were not decommissioned in spite of 120 disclosed troubles and a still-uncertain number of undisclosed troubles (Masai, 2009, p.93).

Table 2 shows the reported hazards from exposure to radiation, such as "cracks in the nuclear reactor" and "loosening of bolts." (Nihon Kogyo Shinbun, 2003, p.14). The troubles were systematic, and the frequent inappropriate handling of the troubles and the complete absence of efforts to revamp the power plants from the ground up represent a lack of concern from the perspective of safety management. This has been the nature of the business ethics – or, rather, the lack of business ethics – exhibited by the Tokyo Electric Power Company over many decades. It is evident that Tokyo Electric Power Company's management places more importance on economical growth than on social welfare (Bertalanffy, 1976, pp.47−48).

Table 2 The Number of Technical Problems at the Fukushima Daiichi Nuclear Power Station. The pink regions indicate the repeated "inappropriate handling" of serious problems, specifically, the concealment of cracks in the shroud (source: Nihon Kogyo Shinbun, 2003, p.14).



IV. Social Responsibility; Systemic Fatigue in Organizational Management

'Shell melt-through' generally means 'melt down'. This occurred already about 1 hour 40 minutes following the earthquake due to a loss of back-up electric generation for the cooling operation. The possibility of this danger had already reported by the Japan Nuclear Energy Safety Organization in October, 2010 (JNES, 2010, p.(4)−7). Although the nuclear policy explicitly states that "even if the probability is low, it is necessary to take steps to remedy possible dangers," measures were not taken. According to the report of the Nuclear Industrial Safety Agency (NISA, 2010, p.1), serious violations of nuclear waste management in nuclear reactors No.1, No.3 and No.5 of the Fukushima Daiichi Nuclear Power Station were pointed out. Moreover, one level 2 violation was pointed out with regard to nuclear waste management, but the troubles were concealed and records falsified by both the Tokyo Electric Power Company and General Electric.

In Figure 3, the filled-in black triangles show the concealed events prior to 2002. Tokyo Electric Power Company did not announce these events in spite of the fact that troubles were experienced at all of their reactors. For example, they found cracks in the 'shroud' which is the cylindrical stainless

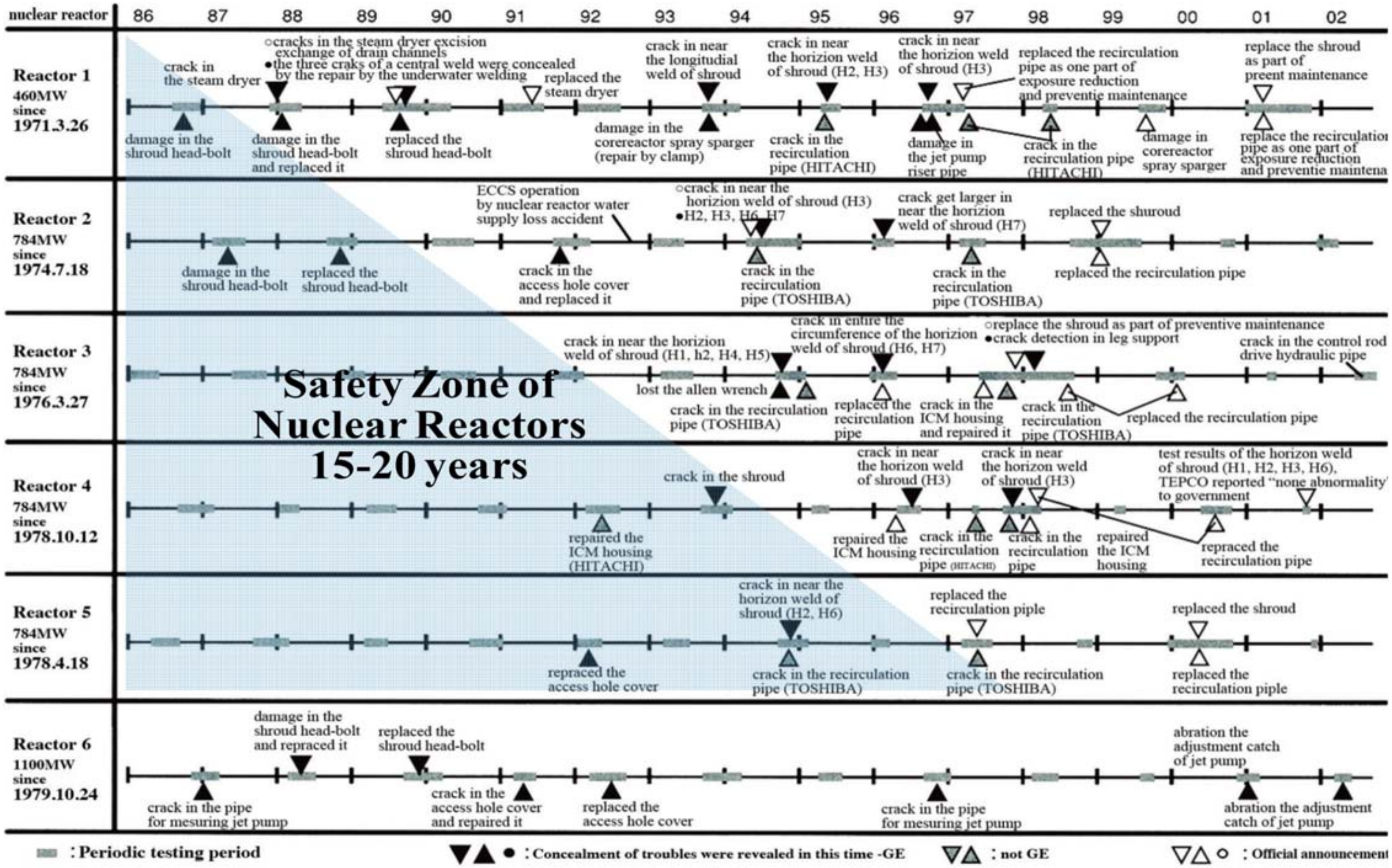


Figure 3 Concealment of troubles and falsification in the records by TEPCO and GE. (source: Genshiryoku siryoushitu, Iwanami No.582, 2002, p.7.) Statically, the blue shade is the safety zone of nuclear reactors – generally suggesting that the trouble-free period is somewhat less than 20 years.

steel cover that surrounds the reactor core, but did not report the actual number of cracks. In addition, from the number of occurrences of trouble, it is evident that nuclear reactors No.3, No.4, and No.5 operate with more stability than No.1 or No.2. As of 1986, 15 years had elapsed since reactor No.1 began operations. In Reactor No.3, the first trouble occurred 20 years from the beginning of operations. No.4 and No.5 experienced troubles after 14 years. In light of these experiences with Reactors 1–5, it can be said that the period of stable operation for these nuclear reactors is about 15–20 years. Unfortunately, if the life of a nuclear power plant is limited to just 20 years, the total cost of nuclear power generation is high, because maintenance and decommissioning will entail a huge expenditure. For this reason, many Japanese Electric Power Companies are in un-competitive situations, and, as a result, the companies are necessarily motivated not to make timely decisions about decommissioning even when circumstances indicate the reality of technical problems.

In light of the current Fukushima disaster, we believe that Japan should take on the mission of establishing new safety guidelines for the operation of nuclear reactors. Specifically, we suggest the following decommissioning standard of nuclear reactors. This decommission formula is based on Fukushima nuclear disaster ($\varepsilon \fallingdotseq \alpha \times \beta \times \gamma \times (\rho + \tau)$). Three variables of function are used in the formula: reactor's age, trouble level, and earthquake level.

‘Fukushima Formula’ of Stopping the Nuclear Reactor for the Local People

$$\boldsymbol{\varepsilon \fallingdotseq \alpha \times \beta \times \gamma \times (\rho + \tau)}$$

ε: decommissioning index of the nuclear reactor
α: age of nuclear reactor (years)
β: trouble level
(level 0: 1.5, level 1: 2.0, level 2: 2.5, level 3: 3.0 over level 4: level)
γ: maximum magnitude of earthquake
(M5.0: 1.5, M6.0: 2.0, M7.0: 2.5, M8.0: 3.0, M9.0: 3.0)
ρ: un-safety management level of organization ($\rho + \tau \geqq 1$)
(Compliance the Law, Corporate Social Responsibility, Business Ethics, industrial pollution)
τ: ambiguity of nuclear policy related the local and globalization

The possibility of ‘Fukushima Formula’ is adjusting the different condition in the world.

(where an ε value greater than 100 would result in decommissioning)

For example, applying Fukushima Daiichi No.1 plant to this standard, the operational term of reactor is 40 years, the trouble level is 2, and the maximum magnitude is M8, giving a decommissioning factors. Fukushima Formula: $\varepsilon \fallingdotseq 40 \times 2.5 \times 3.0$, so $\varepsilon > 100$.

The organizational problems that have plagued the Fukushima nuclear facilities are of three kinds: the construction and later proliferation of nuclear plants in an area where earthquakes and tsunamis are known to occur, frequent troubles because of the ageing of plants designed to last for a standard of 30 years, and finally troubles due to the attempted concealment of events related to accidents and ageing. Including these, there were also problems in safety management. In short, the functioning of "checks and balances" by administrative supervision has not worked well, and we must conclude that the Japanese system for nuclear power plant management has inherent organizational problems with regard to the decommissioning nuclear reactors.

V. Dynamics of System Pathology; Socio-biological Hazards

The following Figure and Table show a comparison between the Fukushima and Chernobyl disasters. On April 12, 2011, the Fukushima nuclear disaster was raised to INES level 7, the same as Chernobyl nuclear disaster.

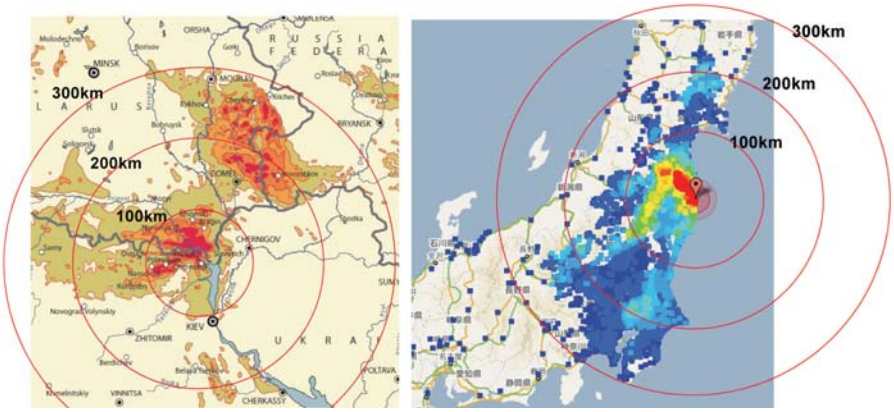


Figure 4 Radiation area of Chernobyl and Fukushima

Table 3 A Comparison of the Fukushima Nuclear Disaster and the Chernobyl Nuclear Disaster (source: IRSN, May 23, 2011, p.28)

	Fukushima		Chernobyl	
Victims	Dead: unknown Radioactive exposure: unknown		Dead: 4,000–16,000 Radioactive exposure: over 830,000	
Radioactive contamination zone	Contamination level	Local people	Contamination level	Local people
	Evacuation zone 20 km	85,000 (628 km^2)	Initialize evacuation zone 30 km	135,000 (2,830 km^2)
	> 300,000 Bq/m^2 (>10 mSv per year)	69,400 (874 km^2)	> 555,000 Bq/m^2 (>7 mSv per year)	270,000 (103.000 km^2)
	> 150,000 Bq/m^2 (> 5 mSv per year)	292,000 (1,241 km^2)	> 185,000 Bq/m^2 (> 2.4 mSv per year)	1,300,000 (19,000 km^2)
Radiological release	3/11~precent spread by air and ocean current		4/26~5/6 spread by air	
Restoration	Over 30 years		Over 30 years (100 years?)	
INES level	7		7	

In the Fukushima case, the supervisory authorities of nuclear power generation in Japan are a double administrative structure. One is a Cabinet Office (Japan Atomic Energy Commission and Nuclear Safety Commission of Japan) and the other is the Ministry of Economy, Trade and Industry (Nuclear Industrial Safety Agency). The reality of multiple supervisory committees makes it unclear where responsibilities lie. Moreover, the practice of former government officials finding employment in the private sector is a widespread problem. Five persons who acted as supervisory authorities later became directors of the Tokyo Electric Power Company (The Mainichi Daily News, April 15, 2011). Clearly, the social function of overseeing the safety of the nuclear power industry has declined and there is a strong possibility that the friendly relations between the supervisory authorities and the industry have had deleterious effects on their watchdog role.

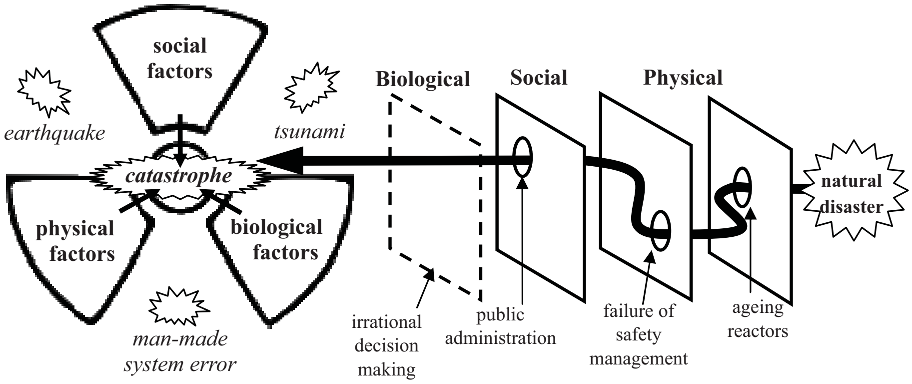


Figure 5　Radioactive Hazards (after Reason, 1997)

These are problems of social responsibility and the dangers of failing to maintain a distinction between public and private sector functions. These aspects indicate the need for '*systems thinking*' and '*systems pathology*' (Troncale, 2011). For instance, Barnard (1938) has emphasized the complex interactions among biological, physical, and social factors. In that light, the Fukushima nuclear catastrophe is clearly an example of the pathology of organizational systems with multiple causes and effects. The deleterious effects of such pathology can perhaps be minimized by working within the conceptual framework of systems theory.

'Systems thinking' can be used to forecast problems arising in other areas in Japan and overseas. The problem of ageing reactors is extremely serious not only in the Tohoku region of Japan, but also with regard to the 13 reactors located in western Japan. This area is called "Genpatsu Ginza", where nearly all of the reactors are ageing systems. For example, the Tsuruga reactor is more than 41 years old and the Mihama reactor is more than 40 years old. Furthermore, many troubles have been disclosed about these reactors. And what is worse, they are located near three geological troughs: the Nankai trough, the Tokai trough and the Tonankai trough. If those troughs synchronized, a massive earthquake would occur, as has in fact taken place every 200 years in Japan.

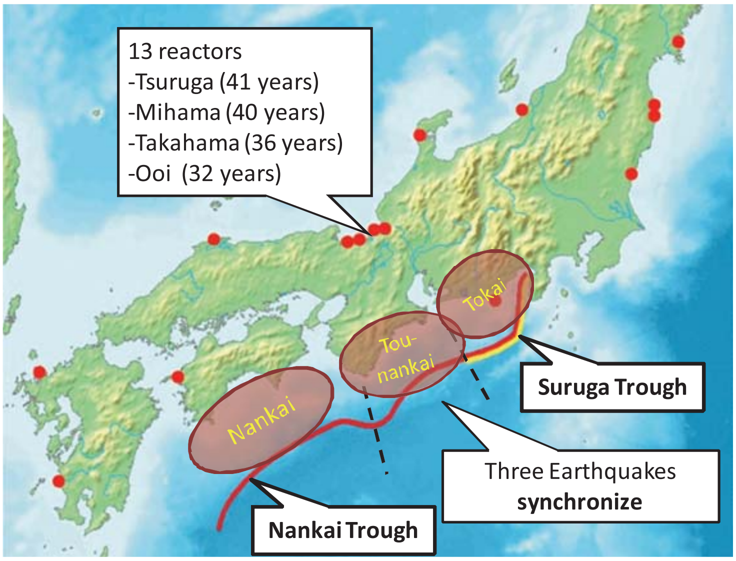


Figure 6 The three troughs forecasting in Western Japan

From a global perspective, it is also important that new international standards be applied to the nuclear power stations currently under construction or planning in the developing world, notably, China and India. Table 4 shows the current state of developments in six of the major nuclear power generating countries. Prior to the recent disaster, Japan operated 54 nuclear reactors, but three quarters have now been stopped. Although it was once said that the level of Japanese nuclear technology was the highest in the world, pervasive problems in management and policy have become evident. In order to avoid repetition of the Fukushima disaster or worse disasters (Chroust, 2011) in the developing world, the enforcement of firm, quantitative standards by *independent* regulatory agencies will be required.

Table 4 A Comparison of Nuclear Systems Worldwide (source: JAIF 2011)

	In operation	Under construction	In planning	Average age
Japan	54	4	11	24
China	13	30	23	26
India	19	8	4	18
Russia	28	11	13	27
USA	104	1	8	30
France	58	1	0	24

VI. Un-Homeostasis; Pathology or Apoptosis?

The Fukushima nuclear power station has continued to operate in spite of signs of ageing and, indeed, until the recent disaster, three new reactors had been scheduled to be built in the same location without first decommissioning the old reactors. The damage of this accident has not been confined solely to the local populace's exposure to radiation; there has also been significant damage to international relations. Various foreign countries have expressed misgivings about the spread of radioactive substances within Japan and their possible spread overseas. Two months following the natural disaster, the damage has continued to enlarge both economically and socially to the entire country. Moreover, the international community has clearly lost confidence in Japan's ability to respond effectively to domestic problems. On the basis of the Fukushima example, local people can judge the risk of nuclear reactors in operation.

Figure 7 shows the world magnitude of plate-type earthquakes. We focus on magnitude near 9.0 since 2000. These big earthquakes form the pacific boundary that is 'Plate's Dogleg'. We adapt to the Fukushima's decommissioning formula toward the world earthquake map. Figure 8 shows the results when the index is applied to nuclear reactors worldwide. Green marks show safe nuclear power plants, orange marks show plants of unknown safety, and red marks show dangerous plants.

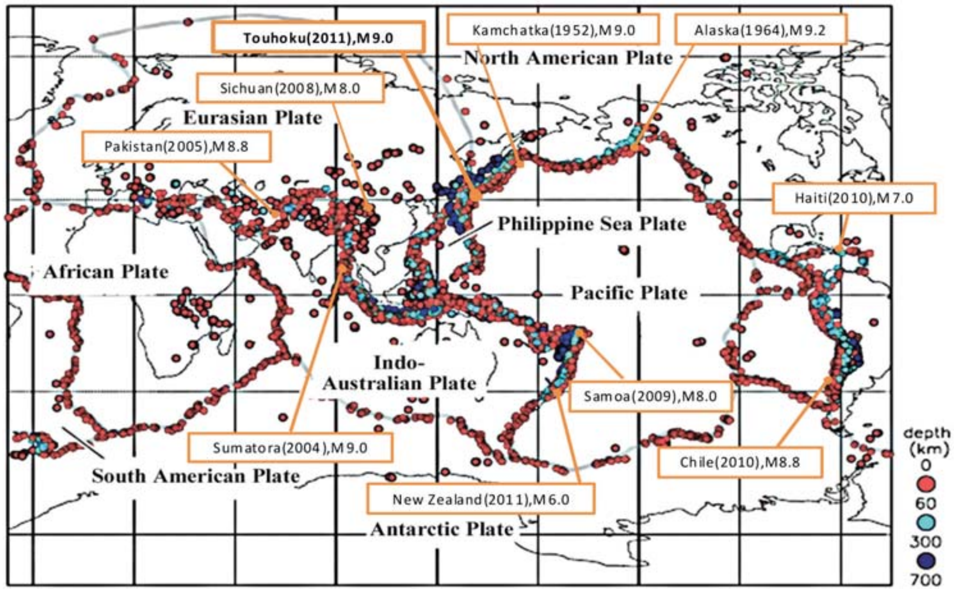


Figure 7 'Plate's Dogreg' area is Magnitude 5.0 or Greater Earthquakes.

(Source: http://www.bousai.go.jp /hakusho/h22/bousai2010/html/zu/zu002.htm).

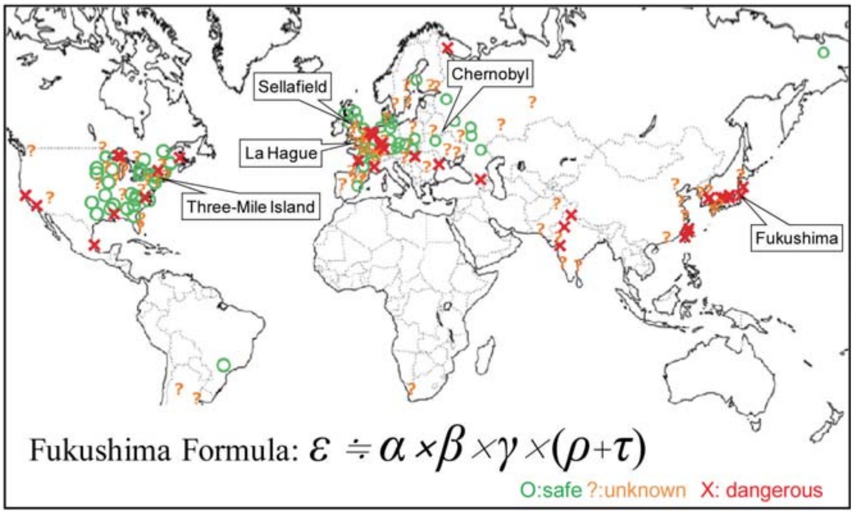


Figure 8 Dangerous Rating of World Nuclear Reactors by ‘Fukushima Formula’.

Insufficient disclosure of information to the residents in the affected area has also become a problem. Although the scale of this earthquake was beyond expectations, many problems have arisen in response to the natural disaster and the extreme vulnerability of countermeasures to the catastrophe was exposed. We recommend that, in the near future, organizations should shift from policy that gives priority to economic profits to policy where safety management and long-term sustainability becomes paramount. Nuclear power generation holds a *dominant* position relative to other means of generating electricity – hydropower, thermal power, wind power, solar power, geothermal power, tidal power – but the dominance is based on the presumption that nuclear reactors have a longevity of at least 40 years. Actually, the cost of constructing nuclear reactors is necessarily high, so that the first 20 years of operation is essentially a period of regaining the initial investment. If, however, the stable lifetime of nuclear reactors is only 20 years, as suggested by the Japanese history of nuclear power generation, then nuclear technology becomes uncompetitive in comparison with other power generation technologies.

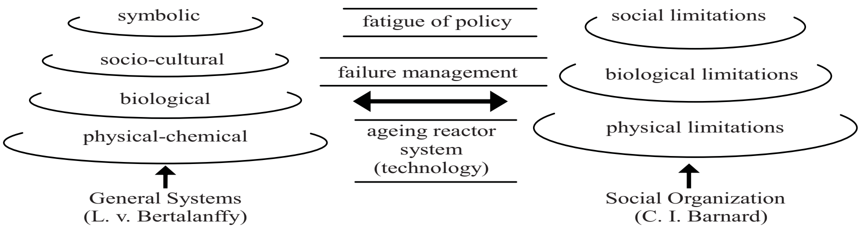
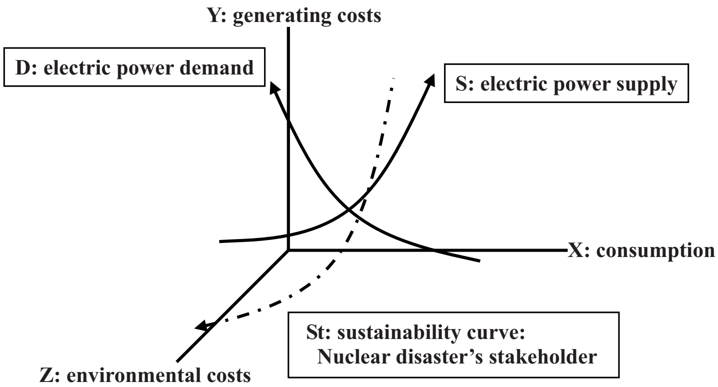


Figure 9 The Multiple Levels of Factors that must be considered in a System’s Approach to the Governance of Nuclear Power Stations.

Finally, it is worth repeating the fundamental idea that initiated the revolution in "general systems theory" some decades ago (Wiener, 1961; Bertallanfy, 1976; Maturana & Varela, 1980). The desirability and viability of nuclear power plants cannot be evaluated without consideration of the social systems in which they are imbedded. The supply-and-demand decisions for economic growth are a necessary part of any social policy, but the wider effects on humanity must also be included. Realistic estimates of the sustainability of the "whole system" require a "systems" perspective.



(restoration for the radioactive damage of ecosystem - including the human society in environment)
Stakeholders: Recovery of radiation area with local people's health, agriculture and marine pollution.

Figure 10　3D-Utility of Power Generation

In light of the Japanese experience, it can be said that decision-making based solely on supply-and-demand was the cause of system pathology. The economic viability of the large-scale nuclear fission power plants that were designed prior to developments in systems theory – and, indeed, prior to the development of modern computers – is questionable. When the economy of nuclear power generation is discussed, the problem of radiation poisoning should not be excluded. For example, the construction cost of a new shelter of the Chernobyl Nuclear Power Plant is 1.6 billion euro, and the maintenance costs are additional. Ukraine cannot pay these costs. Nuclear power generation is not economical and not a sustainable technology if we consider the radiological processing costs and environmental stress. To summarize, the following are organizational problems that could have been avoided. Firstly, the nuclear power plant was constructed in an area where many earthquakes and several tsunamis have occurred. Secondly, there has been a significant number of nuclear power plant troubles due to ageing and, moreover, systematic concealment of those problems. Thirdly, there has been a long-term deterioration of organizational systems, like the safety management of Tokyo Electric Power Company and problems of the administrative supervisory role. At the very least, in the future the Japanese Government and the Tokyo Electric Power Company should disclose accurate information to facilitate local recovery, such that the disclosure of information can be trusted and there is greater faith in the power companies and in the government. This will also help to reduce damage caused by rumours by overseas media.

Consideration of the dangers of nuclear power must be made from a global perspective. We recommend not only stopping the Hamaoka nuclear station but also undertaking independent checking of the 54 reactors in Japan. At the recent G–8 summit meeting held in Deauville, France, on May 26, Japanese Prime Minister Naoto Kan requested to the IAEA, that a new safety standard for nuclear plants be established for quake-prone countries. Properly speaking, however, Japan should make this standard and suggest it to the world. The ongoing Fukushima nuclear disaster has its origins in a failure to think in terms of "whole systems". With only the short-term goals of financial gain and social consensus under consideration, unacceptable risks have been taken in the Japanese nuclear power industry, ultimately leading to large-scale problems for the Japanese population.

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