Rethinking Assumptions: The Post-Fukushima Risk Assessment Controversy

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Assumptions & the Unforeseen: The Meaning of *Sotei* & *Soteigai*

In discussing the Fukushima Daiichi nuclear power plant accident triggered by the Great East Japan Earthquake and ensuing tsunami, Japanese mass media outlets have frequently employed the words *sotei* (assumptions or estimates) and *soteigai* (unforeseen or beyond the scope of assumptions) when asking whether the earthquake, tsunami, and nuclear power plant accident could have been anticipated in advance. Nevertheless, the terms are frequently misconstrued. This essay aims to clarify the causes of such misunderstanding and how we can better prepare for risk.

Basically, *sotei* means a design's target values, or boundary conditions, and is a concept commonly used in engineering when designing equipment, devices or industrial systems. *Sotei* are forward-looking approximations made when conditions are uncertain; clear-cut targets completely free of uncertainty would not be called *sotei*. Any decent designer, therefore, understands there is always the possibility that something may occur to prove the assumptions wrong. The issue is how much to assume about what, and how far to go in preparing for situations that prove the assumptions wrong. Many members of the mass media and other commentators in Japan, however, mistakenly believing that such assumptions should match reality as closely as possible, are quick to make accusations of incompetence and even deliberate negligence when reacting to the slightest misplaced assumption.

In order to avoid misunderstanding and ensure that our discussion of risk assessment is as precise as possible, it is worth noting the five types of situations to which the now frequently discussed concept of *soteigai* is applied:

1) Situations omitted from the assumptions because the likelihood of occurrence was extremely low,
2) Situations omitted from the assumptions because a professional majority felt the likelihood of occurrence was low despite an assertion of probability by a minority,
3) Situations omitted in a trade-off with external factors despite an understanding that there was some likelihood of occurrence,
4) Situations omitted from the assumptions due to overconfidence or pride despite the sense that there was a likelihood of occurrence, and
5) Situations in which the likelihood of occurrence was not even noticed.

Type 1 Situations correspond to the risk of a meteorite scoring a direct hit on a nuclear power plant reactor. Even if this were to fall beyond the assumptions, the public would be forgiving of such "bad luck".

Type 2 Situations are like the assumption of an M9 earthquake and a tsunami greater than 10 meters high. It isn't as if no researchers had pointed out that such a thing were possible, but they did so without any grounding in directly observed, high-precision data. While old documents mentioning enormous earthquakes certainly exist, there is no good way to assess or guarantee the objectivity of descriptions recorded more than 1,000 years ago. The issue of how to evaluate minority views is a thorny one.

Type 3 Situations are a matter of where to draw the line when making trade-offs between safety and cost. From the outside it is difficult to know the true situation with regard to the Tohoku earthquake, but considered in combination with Type 2 Situations it seems reasonable to suggest that electric power corporations are unlikely to adopt safety measures beyond those indicated by public specialized agencies like the Seismological Society of Japan or the Japan Society of Civil Engineers. This is a kind of moral hazard problem.

My impression is that a Type 4 Situation was one of the causes of the Fukushima nuclear power plant accident: the complete loss of power that indirectly led to the core meltdown. After all, the commentary section of the safety guidelines established by the government notes: "There is no need to consider a complete loss of AC power given the expectation that power transmission lines will be restored and emergency AC power equipment repaired within 8 hours." The electric companies have been an easy target for condemnation in the wake of the accident, but isn't it the Japanese government itself that was overconfident in the face of risk?

The main contributors to Type 5 Situations include not only the engineer's lack of information or imagination but also an inability to perform a true assessment due to an overreliance on others. The designer of the General Electric BWR Mark I reactor that was involved in the Fukushima accident had noted the possibility that a loss of cooling function could place a greater-than-anticipated burden on the containment vessel, leading it to rupture. GE responded by asking all Mark I owners to take countermeasures, and indeed Tokyo Electric Power Company made improvements to reactor venting systems and the like. Nevertheless, we cannot deny that the overseas origins of the basic design may have left Japanese companies without a sufficient sense of ownership. With no accidents in 40 years, perhaps there was a degradation of memory, a fading recollection of the procedure that leads from electrical power failure to a pressure increase and then to venting.

As indicated above, the essence of *sotei* depends on how much to assume about what. Still, experts tend to be overconfident in their own areas of specialization and have a bad habit of making assumptions that fit within the range of what they can cover, often resulting in *sotei* that are deep but narrow.

Deciding How Strict the Assumptions Should Be

Another issue is deciding how strict the assumptions should be. There are, though, fundamental difficulties in making highly precise assumptions about natural phenomena such as earthquakes whose causes are hard to observe directly. To avoid criticism later one should adopt the toughest possible assumptions, but given the enormous costs involved this is not a decision so easily made.

When designing actual systems, one generally proceeds on the basis of assumptions. The previously mentioned risk of a meteorite scoring a direct hit on a nuclear reactor, for example, is not one incorporated in actual system design. Even so, important issues should be addressed by responding at a lower level, such as through thought simulations or computer simulations. In this sense, the damage estimate scenarios conducted by the Ministry of Foreign Affairs in 1984 concerning the bombing of a nuclear power plant might be considered something of a landmark. Yet there is an enormous difference in the way such assumptions have been addressed by the United States and Japan. After the tragedy of 9/11 in 2001, the Nuclear Regulatory Commission (NRC) in the United States asked electric companies to estimate and address the risk of a complete loss of power, or damage to spent fuel storage pools, in the event of a suicide attack by terrorists using airplanes, and notified Japan's Nuclear and Industrial Safety Agency (NISA) accordingly. Yet NISA, failing to recognize the importance of this notice, did nothing. One has to conclude that Japan's risk assessment procedures leave it insufficiently prepared for terrorism or other severe accidents.

In the United States, all nuclear reactors are required to undergo mock terrorist attack training once every three years, training that represents real-world operations and goes beyond mere tabletop simulations. Fearing a public outcry, Japan's government and electric power companies have been reluctant to officially announce existing risks. This makes it impossible for them either to win the confidence of the public or to maintain national security. Isn't it about time they stopped hiding behind the excuse that things were *soteigai* and started communicating the risks to the public as precisely as possible, based on the scientific evidence?

Photo: TEPCO/Reuters/AFLO

Smoke is seen coming from the area of the No. 3 reactor of the Fukushima Dai-ichi nuclear power plant in Tomioka, Fukushima Prefecture in northeastern Japan.

The Philosophy & Culture Underlying *Sotei*

The philosophy underlying the concept of *sotei* is that when an assumed risk is unpredictable and broadly anticipated, one adopts the worst possible value within the estimated range. However, as noted above, there is always a limit to how far this value can be maintained when faced with enormous costs.

Culture is also part of the context when it comes to assumptions, and often revealed in the form of the design concept. For example, with respect to the complete loss of power that caused the recent nuclear power plant accident, what was most *soteigai* was that electrical equipment such as the emergency diesel generators and switchboards installed in basements beneath the containment vessels would be inundated by a tsunami. The engineer at GE who designed the reactor is said to have placed such critical emergency equipment safely underground to guard against tornados, the most frequently occurring natural disaster in the United States. Had Japanese engineers been aware of this cultural context, they might have considered where best to install emergency diesel generators from the perspective of Japan's most dangerous natural disasters: earthquakes, tsunami, and floods. The same can be said about the use of venting. It has now become clear that one of the failings of the BWR Mark I type reactor is that a loss of cooling function can cause a greater-than-anticipated build-up of pressure in the containment vessel that leads to rupture. In the United States vents were adopted as a countermeasure in a rational risk trade-off against a reactor explosion and external release of radioactivity. Yet in Japan, bound to the nuclear power industry's dominant doctrine of "control, cool, and contain", there was difficulty in deciding to vent at the appropriate time.

Finally, the most troubling part of all is the huge gulf between Japan and the West with regard to how risk is understood. In the West the concept of risk, whether seen etymologically or in the context of the spirit of the age, is something one chooses to tackle actively and positively. That is, it embodies the spirit of adventure, of taking on challenges. In Japan, however, risk is understood as something negative, as a nuisance that others compel one to address. Frankly speaking, the attitude is that of the well-mannered "good child" piqued at the arrival of a troublesome interloper from the outside.

Instead of risk, the words Japan favors are *anzen* and *anshin* (safety and peace of mind). The problem is that these simply express two values without any concept of probability. Given a choice between two opposites such as safety and danger, or peace of mind and anxiety, the answer is surely clear, but this is not science. Furthermore, there is the enormous drawback that *anzen* and *anshin* cannot be given evidence-based definitions.

In other words, *anzen* and *anshin* are smooth-sounding terms of propaganda. There is nothing wrong with using them in everyday life, but they are unsuitable for the world of scholarship. Indeed, the use of such sentimental words seems to prevent Japanese from correctly understanding the concept of risk. JS

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