POSSIBLE APPLICATION OF FUZZY SET THEORY IN RISK ASSESSMENT, SUBJECTIVE PERCEPTION AND PUBLIC ATTITUDE STUDY ON NUCLEAR ENERGY

Y. Nishiwaki*, H. Kawai, H. Morishima, T. Koga, T. Niwa (1)
T. Terano(2) Y. Harima(3) M. Sugeno(4) S. Kobayashi(5) K. Nakano(6)

(1) Atomic Energy Research Institute of Kinki University, Higashi-Osaka (2) College of Engineering, Hosei University, Koganei, Tokyo (3) Research Laboratory of Nuclear Reactor, Tokyo Institute of Technology, Meguro-ku, Tokyo (4) Department of Systems Science, Tokyo Institute of Technology, Nagatsuda, Midori-ku, Yokohama (5) National Institute of Radiological Sciences, Chiba (6) Kozo Keikaku Kenkyusho K.K., Shinjuku-ku, Tokyo * At present c/o IAEA, Vienna, Austria

I. INTRODUCTION

There are many types of uncertainties involved in risk analysis or risk assessment where biological or medical/societal or humanistic systems are concerned. However, they may be divided into two major categories: the uncertainty due to randomness and that due to fuzziness. Conventional methods of treating the uncertainty are to apply statistical methods of estimation which are, in turn, based upon the concept of probability. Even in the case where the source of uncertainty is of non-statistical nature, formal application of statistical methods of analysis is often done to deal quantitatively with the uncertainty by tacitly accepting the premise that uncertainty - whatever its nature - can be equated with randomness. Most of the works on risk analysis or risk assessment have been done using such methods. The term "probabilistic" is sometimes applied to data even in cases when it is not applicable. The results are often expressed in such terms as "very low probability", while it is not sure whether they should be called "probability" or "possibility". For the analysis of such events, the concept of Fuzzy Set may be applicable, because some uncertainties are accepted as uncertain with introduction of a membership function in the theory of Fuzzy Set. Instead of "0 or 1" or "true or false" of the non-fuzzy binary logic, any intermediate values could be assumed for membership function in Fuzzy Set. The uncertainties are not necessarily probabilistic.

It has been known that much of our real world is more or less fuzzy and a variety of ambiguities are found in our daily conversation. The concept of fuzzy sets seem to be included implicitly or explicitly even in some scientific papers in the past. In the target theory presented by Nishiwaki at the Induced Mutation Session of the International Symposium on Genetics held in Tokyo, 1956, the biological system of a living cell is compared to a complex parallel and series circuit of switches which consist of gene-enzyme system. When such a switching circuit system is irradiated, the switches consisting of gene and enzyme are considered to be disturbed or cut off randomly. The action field of radiation is assumed to vary depending on the quality and type of radiation and the intra-cellular biochemical milieu. When the action field is large with the high LET radiation, multiple switches may be simultaneously destroyed by a single hit and a single hit curve with an apparently large target size may be obtained. When the action field is small with the low LET radiation under anoxic condition, multiple number of independent hits on a multiple number of target switches may be required to produce an

observable effect, and a sigmoid dose-survival curve with a multiple number of small targets or a complex dose-response curve may be observed. In other words, the size of the action field is considered to vary depending on the radiation and the environment and therefore the apparent size of the target may be considered flexible and the boundary more or less fuzzy. The term "fuzzy set" was first proposed by Zadeh in 1965, to describe various types of ambiguity or fuzziness. Some examples of uncertainties associated with frequency perception and judgement on the use of nuclear energy are given in Fig. 1 & 2. The term risk often refers to different types of undesirable effects associated with various activities and its meaning is generally fuzzy. Since the notion of risk in subjective perception or public attitude study must be conceived in terms of the interaction between the object (environment, activity, thechnology,etc.) and the subject (individual, group, society, etc.), a concrete definition of risk must be provided with the specifications of the type "of what", "to whom" and "for what". Presence of the subject in the risk concept is an essential source of fuzziness, because the same ojbect may be differently risky to different subjects who are in different positions and who have different amounts of information, different degrees and types of perception and preference with respect to the object. In this sense, risk is a notion which is not of absolute or objective nature but rather of relative or subjective nature, and therefore, the concepts of fuzzy sets or fuzzy logics seem to be adequate in order to treat the problem associated with risk properly.

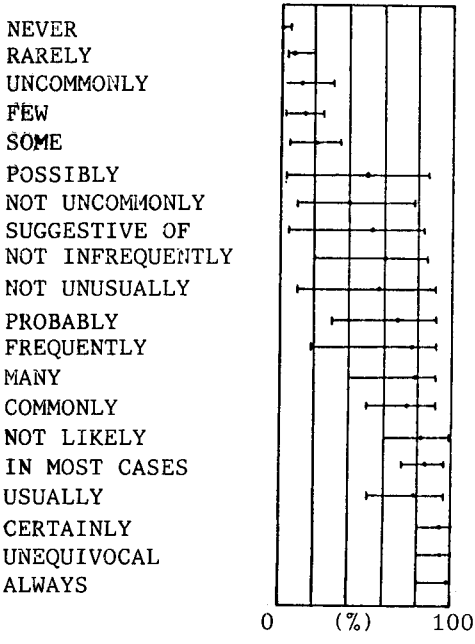

Fig. 1 FREQUENCY PERCEPTION
National Institute of Radiological Sciences (25 scientists)

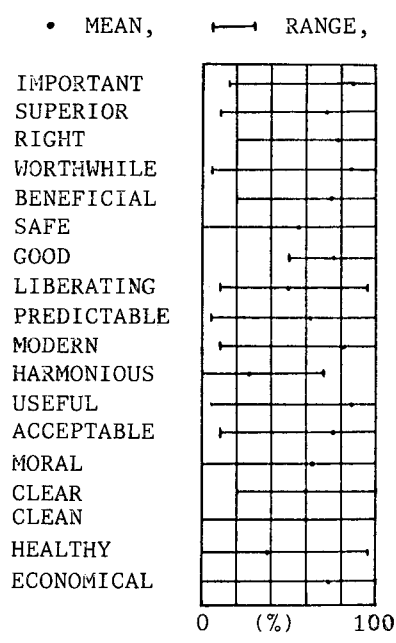

Fig. 2 JUDGEMENT ON THE USE OF NUCLEAR ENERGY
Kinki University (40 students)

II. FUZZY SET AND FUZZY MEASURE

According to Kruse (1983), mathematical concept about fuzziness which is a modality of uncertainty related to the subjective fuzziness of human being may be classified into two categories, one is the fuzzy set proposed by Zadeh (1965) and the other the fuzzy measure by Sugeno (1972). The fuzzy set deals with the relation between non-fuzzy element x and fuzzy subset $\tilde{A}$. On the other hand, the fuzzy measure deals with the relation between fuzzy element $\tilde{x}$ and the non-fuzzy subset B. The fuzzy measure approach generalizes probability measures by dropping the addity property and replacing monotonicity. The possibility measure (Zadeh 1978), belief measure, plausibility measure (Shafer 1976), etc. may be considered a kind of fuzzy measure. As a special form, g_λ measure has the following characteristics:

$$A \cap B = \phi \Rightarrow g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B), \quad -1 < \lambda < \infty$$

When λ=0, it coincides with the probability. The fuzzy integral is a concept of integral using fuzzy measure and may be considered an extension of Lebesque integral. It has a meaning of evaluation of objects by human sujectivity measure. The non-fuzzy linear model can be used only when the attributes are independent. The weighting factor in the linear model does not have such meaning as the grade of importance in the fuzzy model. Regarding the independence, it must be noted that even if physically independent,it may not be considered independent subjectively by the evaluator. In case of fuzzy measure, the assumption of independence is not required.

III. SAFETY ASSESSMENT AND FUZZY DIAGNOSIS

Failure diagnosis is essential for safety assessment of the plants. In case the plant falls in an abnormal condition, it may be desirable to have a device which could diagnose troubles automatically and identify causes of abnormal occurrences in order to prevent serious accidents or danger. However, with the automatic diagnosis devices which are currently employed, there is a possibility of serious misdiagnosis, partly because the logic of diagnosis is itself limited only to the troubles foreseen by man; and partly because a complete detection of all possible abnormalities may not always be possible, whether it be human being or automatic device, as long as a rigid non-fuzzy logic is used. In order to avoid these difficulties, an attempt is made by Terano, et al (1977) to introduce fuzziness in the logic of diagnosis of engine troubles to stimulate human judgement of operators. A more elastic model may be made by modelling the trouble causes and the expression of symptoms with fuzzy sets as a basis of diagnosis and by expressing these relations with fuzzy logics taking into consideration human knowledge and experiences of experts.

IV. PUBLIC ATTITUDE STUDY

For public attitude study, the following model is used. According to Fishbein the attitude A_o toward an object or event may be expressed by the summation of $(b_i \times e_i)$ where b_i = the strength of his belief about object "0", i.e. the subjective probability that "0" is related to some attribute i, e_i = the subject's evaluation of attribute i. However the data obtained in this type of study may be

considered more or less fuzzy. In the fuzzy set model, it may be expressed by the conditional proposition and its truth value: "if A, then B" is R, where $\tilde{A}$, $\tilde{B}$, $\tilde{R}$ are fuzzy sets: R is called linguistic truth value (Fig.3). If we assume A is the cause and B the result, R may be interpreted as a strength of belief about the implication. In the above relation, A_o may correspond to B, e_i to A and b_i to R. As a fuzzy model for the conditional proposition, the following possibilities may be considered: (1) Conditional Proposition and Truth Value Model: $A \rightarrow B$, R; (2) Fuzzy Relation Model: $B = A \circ R$; (3) Fuzzy Integral Model: $B = f\sigma \cdot a$ where σ is conditional fuzzy measure, a is belief measure; (4) Fuzzy Number Equation: $\tilde{B} = \tilde{A} \times \tilde{R}$. In (4), normal mathematical equation may be used with fuzzy numbers for variables. Another effective communication tool for understanding multi-attribute problems would be structural model such as ISM or DEMATEL.

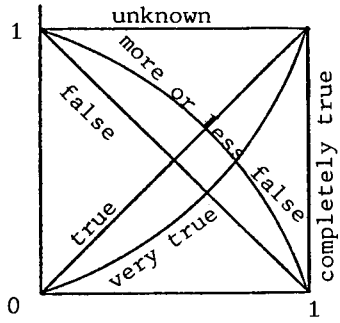

Fig. 3 - Some representative examples of membership functions for liguistic truth values. The truth values expressed with natural languages such as very true, more or less false, etc., are called Linguistic Truth Values (LTV), which may be expressed as fuzzy subset in Truth Value Space [0,1]. In this case, "true" in classical logic corresponds to "completely true" in the diagram. With the fuzzy set, even the qualitative rules expressed in natural languages could be modelled. When the data are more or less fuzzy, the quantitative model based on non-fuzzy logic may not always be the best.

V. CONCLUSION

In risk assessment, subjective perception or public attitude studies, we encounter a variety of sources of uncertainties which are due to ambiguity in our cognition or perception of objects. For systematic treatment of this type of uncertainty, the concepts of fuzzy sets could be applied to construct system models, which may take into consideration such an ambiguity.

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