Modeling Uncertainty with Interval Valued Fuzzy Numbers:
Case Study in Risk Assessment

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ABSTRACT
This article describes how risk assessment is a significant aid in decision-making process. It is usually performed using models and a 'model' is a function of some parameters which are usually affected by uncertainty due to lack of data, imprecision, vagueness, and a small sample size. Fuzzy set is a well-established mathematical tool to handle this type of uncertainty. Normally, triangular fuzzy numbers (TFNs) or trapezoidal fuzzy numbers (TrFNs) are extensively deliberated to embody this type of uncertainty. However, in real world situations, bell-shaped fuzzy numbers may occur to characterize uncertainty. It is pragmatic that type-I fuzzy set may not always dispense single value from [0,1] and on the other hand, assigning a precise value to expert's judgment is excessively restrictive, therefore, the assignment of an interval value is more practical. Thus, interval valued fuzzy set (IVFS) comes into picture. It can be observed that representation of some model parameters of the risk assessment models are triangular interval valued fuzzy numbers (TIVFNs) while representation of some other parameters are bell-shaped IVFNs. In such circumstances, it is most important to devise a technique to combine TIVFNs and bell shaped IVFNs, as they are non-comparable. For this purpose, this article presents a technique to combine both types of incomparable IVFNs within the same framework and finally, a case study is carried out in risk assessment under this setting.

KEYWORDS
Fuzzy Set, Interval Valued Fuzzy Number, Risk Assessment, Uncertainty

1. INTRODUCTION
Risk assessment is an important tool in decision-making process and it is highly important to accrue knowledge on the features of each and every existing data, information and model parameters involved in risk assessment process. It is observed that most frequently existing data/information are construed in probabilistic conceptualization because it is an extremely well-built and well instituted Mathematical apparatus to treat uncertainty (aleatory) that arises due to inherent variability, natural stochasticity, environmental or structural variation across space or time, due to heterogeneity or the random character of natural processes. However, it is comprehensible that not each and every existing data, information and model parameters are influenced by this type of uncertainty and so it cannot be handled by conventional probability theory. However, model parameters may be fouled with uncertainty (epistemic) that arises due to lack of precision, deficiency in data, diminutive sample sizes or data acquisition from specialist opinion or subjective construal of existing data or information. In such situations, conventional probability theory is improper to characterize (epistemic) uncertainty. To overcome the drawback of probabilistic method, L.A Zadeh in 1965 commenced a new notion called fuzzy set theory.

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1.2. Risk Assessment Process

According to United States Environmental Protection Agency, (USEPA) risk is the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor. A stressor is any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact.

Environmental Protection Agency (EPA) uses risk assessment to characterize the nature and magnitude of health risks to humans (e.g., residents, workers, recreational visitors) and ecological receptors (e.g., birds, fish, wildlife) from chemical/radiological contaminants and other stressors, which may be present in the environment. In risk assessment, risk consists of both the probability and impact of disease. So risk reduction can be achieved either by reducing the probability of disease or by reducing its severity.

Health-risk assessment is a quantitative evaluation of information on potential health hazards from exposure to various agents and involves four inter-related steps, namely, Hazard identification; Dose response assessment; Exposure assessment, and Risk characterization.

1.2.1. Hazard Identification

Anything (e.g. condition, situation, practice, behaviour) that has the potential to cause harm, including injury, disease, death, environmental or property and equipment damage is known as hazard. The hazard identification step involves the determination of the adverse effects which may be associated with a biological, chemical, or physical agent has an inherent capacity to cause. It involves gathering and evaluating data on the types of health effects or disease that may be produced by a toxic pollutant and exposure conditions under which environmental damage, injury or disease will be produced.

It is the likelihood of harm due to exposure which distinguishes risk from hazard. The observed effects in humans may include a range of effects; reversible to irreversible such as increase body weight, gain to congenital birth defects, neurological disorder or cancer. Ecological hazards include structural and functional effects.

1.2.2. Dose Response Assessment

Dose-response assessment describes the relationship between the dose of the contaminant and the incidence of adverse health effects in the exposure population. According to EPA, as the dose increases, the measured response also increases (USEPA). At low doses there may be no response. At some level of dose the responses begin to occur in a small fraction of the study population or at a low probability rate. Both the dose at which response begin to appear and the rate at which it increases given increasing dose can be variable between different pollutants, individuals, exposure routes, etc.

1.2.3. Exposure Assessment

EPA defines exposure as ‘contact between an agent and the visible exterior of a person (e.g. skin and openings into the body)’. Exposure assessment is the process of measuring or estimating the magnitude, frequency, and duration of human exposure to an agent in the environment, or estimating future exposures for an agent that has not yet been released. It involves determining the emissions, pathways and rate of movement of a substance and its transformations or degradation in order to obtain concentrations or doses to which human population or environmental components are or may be exposed. Exposure assessment involves describing the nature and size of the population or compartments exposed to a substance, and the magnitude and the duration of their exposure. The evaluation may concern past, or current exposure, or anticipated future exposure.
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