

A Fuzzy Approach for Analyzing the Gap between the Desired and the Current Factors Pertaining to the Research and Development of the Iranian Nanotechnology

Shahla Yassaei and Farhad Ghassemi-Tari

Department of Industrial Engineering

Sharif University of Technology

Tehran, Iran

Sha_yassaei@alum.sharif.edu , ghasemi@sharif.ir

Abstract

In recent years, the non-deterministic approaches for the hypothesis testing of statistical observations and data analysis have attracted great attentions. Descriptive inference statistics, such as point estimators, confidence interval estimators and hypothesis testing mechanisms have been emerged toward application of fuzzy techniques on the data analysis. However, a few efforts have been made on the utilization of the non-parametric techniques for analyzing the fuzzy data. We aimed to correspond to this shortcoming by using Mann-Whitney –Wilcoxon test associated with significance test to fuzzy data. The study draws upon a survey conducted in nanotechnology research and development centers in Iran and tries to analyze the gap between the current situation and ideal factors and dimensions. To this end, we implemented a nine-stage algorithms which helps us to perform non-parametric techniques to fuzzy data.

Keywords

Non-parametric statistics, Test of Hypothesis, Nanotechnology, Research and Development,

1. Introduction

Promoting research and development in nanotechnology field has been an agenda for many governments, universities, and to a lesser extent in private sector. Besides the countries efforts to establish or plan to establish their national programs, a global strategy of mutual interest is envisioned by connecting individual programs of contributing countries, professional communities, and international organizations. In this regard the main issue for Iran is how to be in the right position on this technology development.

Nanotechnology research and development includes control and material manipulation at the nanoscale, and integration of nanoscale structures into larger material components, systems and architectures (Roco, 2001). While nanotechnology was seen as too far from industrial practice before 1998, perception changed significantly following expansion of the R&D research worldwide, which caused a second shift and a potential to become a paradigm shift in economy as industry and business groups become convinced.

From the current broad opportunities of R&D start-ups, countries are developing areas responding to their own expertise and needs. The focus varies from a general science-based strategy (i.e. U.S. and France) to industry relevance driven strategy (i.e. EC, Korea and Taiwan), from broad spectrum of areas (as in U.S., Japan and Germany) to specific strengths. The main difference among countries is the time scale and research area domain that are targeted. It is interesting to know that about \$1 trillion products had been estimated to be affected by nanotechnology until 2015 (Roco & Bainbridge, eds., 2001).

Nanotechnology is overlapping with other research fields, not replacing them. Partnerships between universities, industry, and business are growing within and across national boundaries faster than the R&D activity itself. Industry and business are generally interested in ‘vertical’ transforming of fundamental discoveries into products, while academic activities are generally directed to ‘horizontal’ basic discoveries of relevance to multiple disciplines and areas of application.

On human performance a main challenge is to educate and train a new generation of skilled workers with multidisciplinary perspectives necessary for rapid progress in nanotechnology as well as addressing sustainable development and processes in the environment (such as chemical decontamination of soils, water desalination, solar energy conversion and increase efficiency of lightning. International partnerships are particularly suitable for academic research, common R&D objectives and cost leveraging of expensive facilities and experiments. Therefore, shared R&D projects, enhancing communication, networking for exchanges of peoples and ideas, and developing of R&D partnerships are expected to expand.

The expansion of networking among nanotechnology scientists and other researchers can be regarded in published statistics. According to the statistics published in StatNano website, over nine percent of all scientific articles published in 2014 are allocated to nanotechnology. China, USA and India have published the highest number of ISI-indexed nanotechnology articles in 2014. The capacity to collaborate is also important in Iran as Iran possesses 7th rank in the production of nanotechnology articles while standing the second among the Islamic countries as well (Iran nanotech. Initiative Council INIC, and StatNano 2014).

The trend of nanotechnology growth and development in Iran sparked in 2001. In 2003 nanotechnology strategic plan was prepared and handed over to the cabinet by Iran Nanotechnology Initiative Council (INIC) which established in 2003. The plan was approved in 2005 by the cabinet. Policies and strategic plans for the improvement and development of nanotechnology were approved in 2006 and afterward many workgroups including Tech-Market Services, Corridor, Nanotechnology Development, Human Resources Development, Technology Infrastructures, Promotion and Culture-making, International Affairs, and Policy-making and Evaluation Workgroups have been created by INIC.

Iran Nanotechnology Strategic Plan is a ten-year plan that started in 2005 and ends in 2014. Nanotechnology strategic plan for the next 10 years is being devised at the moment, and it includes the period between 2015 to 2025. The main goal of the first ten-year strategic plan is the production of wealth and improving life quality of the people. One of the major missions in the plan is that Iran must be among the top 15 countries by 2014. To this end, various strategic programs have been considered in the plan to develop human resources, production of science, development and innovation development, and finally the production and commercialization of products and the presentation of the products to the international markets.

Iran's national priorities in the field of nanotechnology includes Energy, health, water and environment, construction, and nanomaterials industry. Taking into consideration the fact that petroleum and gas are among the main industries in Iran, energy zone is the main priority in the field of nanotechnology research and therefore fuel cells and petrochemical industries are among national priorities in the field of energy.

Public promotion of nanotechnology is one of the unique characteristics of nanotechnology development program in Iran in comparison with other countries. Significant attention to public education of nanotechnology, especially at school level, is clearly observed in Iran. Iran Nanotechnology Initiative Council established Nano Club to improve the familiarity of school students with nanotechnology and nanosciences, and to create an environment for the students to carry out research in this field. The innovative organization of Nano Olympiad is one of the promotional programs in Iran. The Club tends to guide students through an educational process from learning basic concepts to creating knowledge-based ideas, so that their academic research will be based on what they have learned and experienced in Nano Club after their graduation..

Taking into consideration the importance of training nanotechnology experts, PhD courses have been organized in the field of nanochemistry, nanophysics, nanomaterials, nanomedicine in 15 universities in Iran in the past 10 years. 1554 PhD theses have so far been carried out and 1040 these are being carried out at the moment. The number of the scientific boards in universities, active in the field of nanotechnology reached 2632 in 2013. In addition, many books have been published in the field of nanotechnology, among which mention can be made of 32 international books and 126 volumes of books in Persian. (Iran nanotech. Initiative Council, INIC 2014, and nano.ir).

Iran Nanotechnology Laboratory Network was established to share knowledge and facilities in the field of nanotechnology. A number of 57 research centers have so far joined Nanotechnology Laboratory Network, and they have shared 852 devices through the network. Approximately 100,000 services have been provided for the

customers in the network in 2013. Nanotechnology Laboratory Network started to establish expert workgroups in 2009, and six workgroups are currently active in TEM, SEM, X-ray, SPM, standard and calibration, chromatography, and element analysis zones (Iran nanotech. Initiative Council INIC, 2014, and nanoLab.ir).

Nanotechnology Standard Committee was established in 2006, aiming to devise and publish standards in the field of nanotechnology. The Committee is an active member of ISO/TC229 International Committee, and it has so far published 15 national and two international standards, and it is currently devising 10 other national and one international standards. Iran Nanotechnology Safety Network has aim to create an appropriate environment for researchers and related centers in the country to carry out their activities in the framework of the specified programs supervised by the network, focusing on the devising standards, regulations, and instructions on safety and environmental issues in nanotechnology. Therefore, it will be able to play an important role in the safe development of nanotechnology products in a mid-term outlook

As to International Cooperation, Nanotechnology Initiative Council proposed the establishment of the Eco Nano Network in 2009, and the objectives of the network were to improve nanotechnology level among Eco member countries, to exchange experiences and skills among these countries, develop economic share of Eco in knowledge-based exchanges, create regional and international market for nanotechnology products, and finally improve life standards in these countries. The International Center on Nanotechnology for Water Purification (UNIDO) is located in Tehran, and Iran is responsible for the management of the center. Iran has carried out many joint projects with Germany, Russia, India, Taiwan and South Korea, and is an active member of the Asia Nano Forum (ANF).

As to the trend of product commercialization, the challenges in the path to grow and develop scientific findings in universities and to present the findings to the market are among the problems in the commercialization of the academic achievements. The process to convert an idea to a product requires various informative, managerial, legal and financial infrastructures. Tech-Market Services Corridor has taken into consideration all these needs, and it has located active units in the field of specialized technology services in an integrated complex. The Corridor has a unit to inspect and evaluate nano-materials and nano-products, which evaluates nanotechnology-based products and grants them with nanoscale certificate. The unit is also in charge of supervising scale registration for the products that have acquired nanoscale certificate. In the past 10 years, 143 nanotechnology-based companies have been established in eight different industries in Iran. Half of the companies are active in the field of health, drug, and materials. Facilities, construction, and building ranked second in the ranking of companies active in the field of nanotechnology (Iran nanotech. Initiative Council INIC, 2014, and nano.corridor.ir).

In this study, we attempt to analyze the gap between current (perceptions) and ideal (expectations) conditions of R&D factors in Iranian nanotechnology via fuzzy approach by using non-parametric techniques. It should be noted that no previous research has been done in the country to analyze the gap between nanotechnology research and development factors using fuzzy method.

1.1 Hypothesis: To response the main objective of our study, understanding the gaps of the related R&D factors in Iran nanotechnology sector, we define the following hypothesis using crisp method. We test the hypothesis using fuzzy approach and therefore, the results should be returned thereafter.

Null hypothesis (H_0): No significant difference exists between perceptions of current situation and expectation of an ideal situation in Iran's nanotechnology research and development initiatives, in the following dimensions: rules and regulations, awareness, innovative idea, investment, external relations, human resources, social responsibility, and international cooperation.

2. Data

The study is based on a cross-sectional survey and conducted among industry experts and university academia using structured questionnaire and Ching's fuzzy numbers and linguistic index (Ching et al, 2005). After in-depth study of literature, we identified 27 factors that categorized into 8 groups. Validity and reliability of the questionnaire were confirmed using content validity and Cronbach's alpha coefficient (0.961), respectively.

3. Method

Many aspects of different activities in the real world cannot be assessed in a quantitative form, but rather in a qualitative one. In that case, a better approach may be the use of linguistic assessments instead of numerical values. The fuzzy linguistic approach represents qualitative aspects as linguistic values by means of linguistic variables (Zadeh 1975). However, care must be applied that such a methods, neglect ambiguity related to individuals judgment and their value changes during transformation to numbers (Chakraborty, 1975). when the research is in a qualitative environment and knowledge therein suffer from ambiguity and vagueness, data may not be expressed as exact numbers, as if in the most researches it is claimed that the most of managers cannot express an exact number in order to present their opinion and therefore linguistic assessment is used instead of specific numerical values (Beach et al., 2000; Gerwin, 1993;). Regularly, a proper linguistic variable is set up for explanation of ambiguity and vagueness base on the problem domain. Then, expressions' concept would be determined using fuzzy numbers, which are defined through space $[1, 0]$ and membership function. Since linguistic assessment is approximate, triangular and trapezoidal membership functions seem to be appropriate for responding ambiguity of these assessments (Delgado et al., 1993). Several researchers have shown that fuzzy membership function can reflect in mind the relative importance of linguistic words (Dyer and Sarin, 1979).). As if nowadays, the applicability of such an approach is more and more visible in the following fields: information retrieval (Bordogna and Pasi, 1993), education (Law, 1996), suppliers' selection (Herrera et al., 1999) and decision making (Tong and Bonissone, 1980; Delgado et al., 1993; Yager, 1995; Herrera et al., 1995).

The ambiguity and uncertainty existing in human assessment makes the crisp methods as inexact methods. By considering the uncertainty and ambiguities, the fuzzy logic provides a suitable tool for evaluating human factors. However, few efforts,if any, have been devoted in applying non-parametric techniques to fuzzy data.

In this paper, an attempt is made to response the issue by proposing extensions of non-parametric statistics (Mann-Whitney and Wilcoxon Test) and associated significance tests to fuzzy data.

First of all, we discuss some relevant concepts and theorems such as crisp ordering relations, fuzzy partial order and the concept of significance test and later on introduce our approach.

3.1 Crisp Ordering Relations

A crisp binary relation on a set U is a crisp subset $R \subseteq U^2$. In the sequel, U will always be assumed to be finite. The notation uRv will be used as a shortcut for $(u, v) \in R$. A relation R is a partial order if it is antisymmetric and transitive. An irreflexive partial order is said to be strict. By default, all partial orders considered in this paper will be assumed to be strict. A linear order is a complete partial order. In the sequel, $\mathcal{P}U$ and $\mathcal{L}U$ will denote, respectively, the sets of partial and linear orders on U . A linear order L is a linear extension of a partial order P if and only if $P \subseteq L$. In other word every partial order has at least one linear extension. The set of linear extensions of a partial order P will be noted $(P) \subseteq \mathcal{L}U$. In many situations $U = \{u_1, \dots, u_n\}$ is a set of n objects of a population Ω , described by a continuous variable $X: \Omega \rightarrow \mathbb{R}$. Let $x_i = X(u_i)$, $i = 1, \dots, n$.

3.2 Fuzzy Partial Order Induced by Fuzzy Intervals

Assume that the unknown values $x_i : (i = 1, \dots, n)$ are constrained by fuzzy intervals \tilde{x}_i , $i = 1, \dots, n$. The membership function $\mu_{\tilde{x}_i}$ is a possibility distribution related to the unknown value of x_i . Let \tilde{x}_i and \tilde{x}_j be two fuzzy intervals related to two values x_i and x_j . Assuming \tilde{x}_i and \tilde{x}_j to be non interactive, the possibility distribution concerning the joint values (x_i, x_j) is given by:

$$\mu_{(\tilde{x}_i, \tilde{x}_j)}(x_i, x_j) = \mu_{\tilde{x}_i}(x_i) \wedge \mu_{\tilde{x}_j}(x_j) \quad (1)$$

According to this possibility distribution, the necessity of the event $x_i \leq x_j$ is given by:

$$\mu_{\tilde{p}}(u_i, u_j) = N(x_i \leq x_j)$$

$$\begin{aligned}
N(x_i \leq x_j) &= 1 - \prod (x_i > x_j) \\
&= 1 - \sup_{x_i > x_j} \mu_{\tilde{x}_i}(x_i) \wedge \mu_{\tilde{x}_j}(x_j)
\end{aligned} \tag{2}$$

This quantity is used to compare fuzzy numbers (Dubois and Prade 1998). Let $\mu_{\tilde{P}}(u_i, u_j) = N(x_i \leq x_j)$. This fuzzy relation is antisymmetric and transitive: it is a fuzzy partial order on U . Note that this relation is dual to the fuzzy relation $\mu_{\tilde{R}}(u_i, u_j) = \prod (x_i > x_j)$. we have $\mu_{\tilde{P}}(u_i, u_j) = 1 - \mu_{\tilde{R}}(u_i, u_j)$ for all u_i, u_j . Hence, \tilde{P} is the fuzzy counterpart of P and will be extended as follows: $\tilde{P} = \pi(\tilde{x}_1, \dots, \tilde{x}_n) \varepsilon \tilde{P}u$ where $\tilde{P}u$ denotes the set of fuzzy partial orders on U . The relationship between \tilde{P}, P is given by the following theorem.

- **Theorem 1:** Let $\tilde{P} = \pi(\tilde{x}_1, \dots, \tilde{x}_n)$ be the fuzzy partial order on U induced by the fuzzy numbers x_1, \dots, x_n . We have:

$$\tilde{P}^\beta = \pi(\tilde{x}_1^{(1-\beta)^+}, \dots, \tilde{x}_n^{(1-\beta)^+}), \forall \beta \varepsilon [0, 1]; \tag{3}$$

$$\tilde{P}^{\beta+} = \pi(\tilde{x}_1^{(1-\beta)^+}, \dots, \tilde{x}_n^{(1-\beta)^+}), \forall \beta \varepsilon [0, 1]; \tag{4}$$

Proof. For all β membership

$$\begin{aligned}
&\forall (i, j) \varepsilon [1, \dots, n]; \\
(u_i, u_j) \varepsilon \tilde{P}^\beta &\Leftrightarrow 1 - \sup_{x_i > x_j} \mu_{\tilde{x}_i}(x_i) \wedge \mu_{\tilde{x}_j}(x_j) \geq \beta \\
&\Leftrightarrow \sup_{x_i > x_j} \mu_{\tilde{x}_i}(x_i) \wedge \mu_{\tilde{x}_j}(x_j) \leq 1 - \beta \\
&\Leftrightarrow \forall (x_i, x_j) \varepsilon \mathfrak{R}^2, x_i > x_j \Rightarrow (\mu_{\tilde{x}_i}(x_i) \wedge \mu_{\tilde{x}_j}(x_j) \leq 1 - \beta) \\
&\Leftrightarrow \forall (x_i, x_j) \varepsilon \mathfrak{R}^2, x_i > x_j \Rightarrow (\mu_{\tilde{x}_i}(x_i) \leq 1 - \beta \quad \mu_{\tilde{x}_j}(x_j) \leq 1 - \beta) \\
&\Leftrightarrow \forall (x_i, x_j) \varepsilon \mathfrak{R}^2, (\mu_{\tilde{x}_i}(x_i) > 1 - \beta \quad \mu_{\tilde{x}_j}(x_j) > 1 - \beta) \Rightarrow x_i \leq x_j \\
&\Leftrightarrow \tilde{x}_i^{(1-\beta)^+} < \tilde{x}_j^{(1-\beta)^+}
\end{aligned}$$

The proof is the same for this theorem when the Relations 3 and 4 are unequal.

- **Theorem 2:** Let $\tilde{P} = \pi(\tilde{x}_1, \dots, \tilde{x}_n)$ be the fuzzy partial order induced by n fuzzy intervals x_1, \dots, x_n . Let $\Lambda(\tilde{P}) \varepsilon [Q1]^{L_u}$ be the fuzzy set of linear extensions of \tilde{P} . We have, for all $L \varepsilon L_u$:

$$\mu \Lambda(\tilde{P})^{(L)} = \sup_{L-\lambda(x_1, \dots, x_n)} \mu_{\tilde{x}_1}(x_1) \wedge \dots \wedge \mu_{\tilde{x}_n}(x_n). \tag{5}$$

At this point, we extend Mann-Wiethny statistic to fuzzy data:

3.3 Fuzzy rank correlation between two fuzzy partial orders

As before, let us denote by $(E_1, P_1), \dots, (E_n, P_n)$ the values taken by two continuous Variables (E, P) for n members of a population. We now assume that, because of the imperfectness of the observation process, these values are only partially known, and are constrained by possibility distributions. The available data thus consists of n pairs of fuzzy numbers $(\tilde{E}_1, \tilde{P}_1), \dots, (\tilde{E}_n, \tilde{P}_n)$. Let ω denote the fuzzy set of possible values for the Mann-Whitney statistic, and defined as:

$$(E_1, P_1), \dots, (E_n, P_n) \rightarrow \tau(\lambda(E_1, \dots, P_n), (E_1, \dots, P_n)). \quad (6)$$

Its membership function is thus defined as:

$$\begin{aligned} \mu_{\omega}(\omega) &= \sup_{\omega=\omega(\lambda(E_1, \dots, E_n), (P_1, \dots, P_n))} \left(\bigwedge_{i=1}^n \mu_{\tilde{E}_i}(E_i) \right) \wedge \left(\bigwedge_{i=1}^n \mu_{\tilde{P}_i}(P_i) \right) \\ &= \sup_{\omega=\omega(L_E, L_P)} \left(\sup_{L_E=\lambda(E_1, \dots, E_n)} \bigwedge_{i=1}^n \mu_{\tilde{E}_i}(E_i) \right) \wedge \left(\sup_{L_P=\lambda(P_1, \dots, P_n)} \bigwedge_{i=1}^n \mu_{\tilde{P}_i}(P_i) \right) \end{aligned} \quad (7)$$

As to Theorem 2, this is equal to:

$$\mu_{\omega}(\omega) = \sup_{\omega=\omega(L_E, L_P)} \mu_{\wedge(\tilde{P}_E)}(L_E) \wedge \mu_{\wedge(\tilde{P}_P)}(L_P) \quad (8)$$

With $\tilde{P}_E = \pi(\tilde{E}_1, \dots, \tilde{E}_n)$ and $\tilde{P}_P = \pi(\tilde{P}_1, \dots, \tilde{P}_n)$, therefore

$$\omega^{\beta} = \left\{ \omega(L_E, L_P), L_E \varepsilon \wedge(\tilde{P}_E)^{\beta}, L_P \varepsilon \wedge(\tilde{P}_P)^{\beta} \right\} \quad (9)$$

From Theorem 3: Let \tilde{P} be a fuzzy partial order on U, and $\wedge(\tilde{P}) \varepsilon [Q1]^{L_U}$ the fuzzy set of linear extensions of \tilde{P} . We have:

$$\omega^{\beta} = \left\{ \omega(L_E, L_P), L_E \varepsilon \wedge(\tilde{P}_E)^{(1-\beta)+}, L_P \varepsilon \wedge(\tilde{P}_P)^{(1-\beta)+} \right\} \quad (10)$$

Now, we propose to estimate ω approximately in region convex statistic

$$\omega^{\beta} = \left[\min_{L_E \varepsilon \wedge(\tilde{P}_E)^{(-\beta)+}, L_P \varepsilon \wedge(\tilde{P}_P)^{(-\beta)+}} \omega(L_E, L_P), \max_{L_E \varepsilon \wedge(\tilde{P}_E)^{(-\beta)+}, L_P \varepsilon \wedge(\tilde{P}_P)^{(-\beta)+}} \omega(L_E, L_P) \right] \quad (11)$$

$$\omega^{\beta} = \overline{\omega} \left(\pi(\tilde{E}_1^{\beta}, \dots, \tilde{E}_n^{\beta}), \pi(\tilde{P}_1^{\beta}, \dots, \tilde{P}_n^{\beta}) \right) \quad (12)$$

As to the above theorems, we can estimate fuzzy convex hull of each statistic. Hence, we run for non-parametric Mann-Whitney test as below:

3.4 Significance Test

To confirm or reject hypothesis tests, it is required to identify the significance level which is the same as probability $\tilde{P}(\omega)$, therefore, with regard to Mann-Whitney test statistic and its fuzzy extension we can define it as:

$\tilde{P}(\varpi)^\beta = [P^-(\varpi)^\beta, P^+(\varpi)^\beta]$, with β -cut membership and by extending fuzzy convex region to significance test, the result of the same possibility distribution, $\mu_{\tilde{\varphi}_\alpha}$ on $\{0,1\}$ is defined as:

$$\mu_{\tilde{\varphi}_\alpha}(0) = \sup_{p>\alpha} \mu_{\tilde{p}}(p), \quad (13)$$

$$\mu_{\tilde{\varphi}_\alpha}(1) = \sup_{p\leq\alpha} \mu_{\tilde{p}}(p). \quad (14)$$

In the aforesaid relations, α is first type error and p is significance level. H_0 and H_1 is in fact the maximum degree of membership where $P > \alpha$ and $P \leq \alpha$. It is obvious that when $\mu_{\tilde{\varphi}_\alpha}(1) = 1$, null hypothesis H_0 is rejected and when $\mu_{\tilde{\varphi}_\alpha}(0) = 0$, H_0 is not rejected.

Therefore, the result of the fuzzy test is two quantitatives $\mu_{\tilde{\varphi}_\alpha}(1)$ and $\mu_{\tilde{\varphi}_\alpha}(0)$ of fuzzy subset $\{0,1\}$.

3.5 Mann-Whitney-Wilcoxon two-sample test

The Mann-Whitney-Wilcoxon two-sample test is based on the Wilcoxon two-sample rank sum statistic ω defined as follows.

Let x_1, \dots, x_n and y_1, \dots, y_m be two independent samples. Combine the two samples, and order the resulting sample of size $N = n + m$. Let r_i be the rank of x_i in the combined sample. Then $\omega = \sum_{i=1}^n r_i$, the sum of ranks of the observations. the two samples have the same distribution, the mean and variance of ω are:

$$E(\omega) = \frac{n(N+1)}{2} \quad (15)$$

$$Var(\omega) = \frac{nm(N+1)}{12} \quad (16)$$

and the distribution of ω can be considered to be approximately normal whenever n and m are greater than 10. The null hypothesis can then be rejected at the α level, when:

$$\left| \omega - \frac{n(N+1)}{2} \right| > \phi^{-1} \left(1 - \frac{\alpha}{2} \right) \sqrt{\frac{nm(N+1)}{12}} \quad (17)$$

3.6 Extension to fuzzy data

Let Z_1, \dots, Z_n denote the combined sample, and $L = \lambda(Z_1, \dots, Z_n)$. The Wilcoxon statistic depends only on L and may be noted $W(L)$. Let Z_1, \dots, Z_n be n fuzzy intervals defining fuzzy constraints and $\tilde{P} = \pi(\tilde{Z}_1, \dots, \tilde{Z}_n)$ be the corresponding fuzzy partial order. The fuzzy Wilcoxon statistic may be defined as the fuzzy interval for all $\beta \in (0,1)$ with β -cut.

$$\varpi^\beta = \left[\min_{L \in \lambda(\tilde{P}^{(1-\beta)^+})} \omega(L), \max_{L \in \lambda(\tilde{P}^{(1-\beta)^+})} \omega(L) \right] \quad (18)$$

Let U^- and U^+ denote the lower and upper bounds of $\omega(L) - n(N+1)/2$ for all $L \in \Lambda(\tilde{P}^{(1-\beta)^+})$. The β -cut of $\tilde{P}(\omega)^\beta$ of $\tilde{P}(\omega)$ is the closed interval as:

$$P^-(\omega^\beta) = 2 \left[1 - \phi^{-1} \left(\max(U^+, -U^-) \sqrt{\frac{12}{nm(N+1)}} \right) \right], \quad (19)$$

$$P^+(\omega^\beta) = 2 \left[1 - \phi^{-1} \left(\max(U^-, -U^+) \sqrt{\frac{12}{nm(N+1)}} \right) \right], \quad (20)$$

3.7 Extension of Wilcoxon fuzzy test to hypothesis

We continue by applying Wilcoxon fuzzy test on our hypothesis or in other words on the gap between perceptions and expectations of Iran nanotechnology research and development factors. The algorithm includes 9 stages as below (Denoeux 2005).

- **First Stage:** Figure 1 displays the Fuzzy numbers of 97 under-study population of the variables perceptions (P) – expectations (E) associated to rules and regulations. Because of the similarity of respondent views, fuzzy numbers are less than actual respondents. As mentioned earlier we must determine the confluence of the numbers as pair-wise to access their fuzzy linear extension and define the maximum membership degrees as to preference of one over the other.
-

$$\mu_{\tilde{R} \cdot \tilde{Q}}(E, P) = \bigvee_v \mu_{\tilde{R}}(E, P) \wedge \mu_{\tilde{Q}}(E, P), \quad \forall (E, P) \in U^2 \quad (21)$$

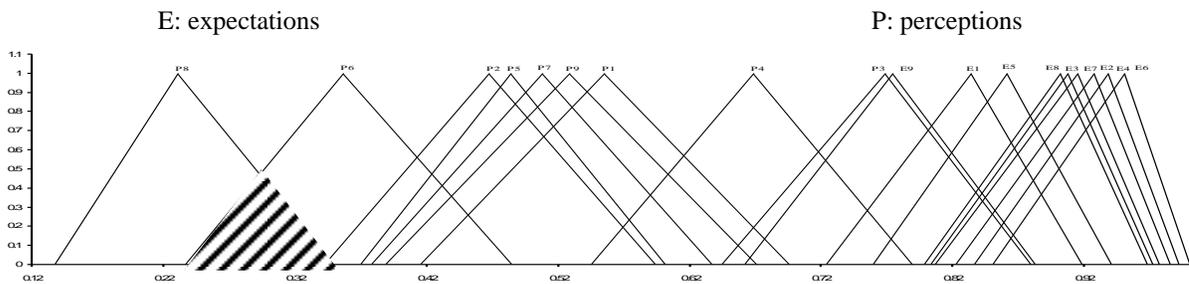


Figure 1: Fuzzy numbers of perceptions-expectations associated to rules and regulations

- **Second Stage:** Formation of pairwise comparison matrix
All fuzzy numbers (not just numbers associated with perception-expectation) sort out as pair-wise comparison matrix and their membership degrees as to preference of one over the other be calculated by relation No.21. Some part of this matrix are shown in table 1.

Table1: Pairewise comparison matrix for perception-expectation

	E_1	E_2	E_3	E_4	\dots	P_1	P_2	P_3	\dots	P_9
E_1	0	1	0	0	\dots	0	0	0	\dots	0
E_2	0.974	.	.	.	\dots	.	.	.	\dots	0
\vdots										
P_9	1	1	1	1	\dots	0.571	0.857	0	\dots	0

- **Third Stage:** Define partial order set
Upon formation of pairewise comparison matrix, now we define partial order for all approved membership region. Following some samples are suggested according to their membership degree.

$$\Lambda \tilde{P}^{0+} = \{(E_2, E_1), \dots, (P_8, P_9)\}$$

$$\vdots$$

$$\Lambda \tilde{P}^{0.947+} = \{(E_6, E_1), \dots, (P_7, P_9)\}$$

- **Fourth Stage:** Formation of linear extension
Each linear order is a complete partial order, so by forming sets of partial order with β -cut memberships, we access sets of linear order depending on β membership functions on (0,1).

$$A\tilde{P}^{0+} = \{(P_8, P_3, P_9, P_7, P_4, E_2, P_6, P_1, E_9, E_4, P_5, E_5, E_8, E_3, E_7, E_6, E_2, E_1)\}$$

$$\vdots$$

$$A\tilde{P}^{0.947+} = \{(P_8, P_7, P_3, P_2, P_9, P_4, E_8, E_6, E_3, E_1, P_6, P_1, E_9, E_7, E_4, E_2, P_5, E_5)\}$$

- **Fifth Stage:** Calculation of fuzzy rank interval
With regard to maximum and minimum rank of membership degree in each linear order we define fuzzy rank interval. ϖ (mentioned below) denotes for fuzzy interval and present sum of ranks assigned to fuzzy numbers associated with perceptions- expectations.
- **Sixth Stage:** Determine fuzzy rank intervals (ϖ) and their membership degrees (μ_{ϖ})
At this part of Wilcoxon test we determine commonalities among estimated data of fuzzy sets until the fuzzy rank intervals be finalized. Then we calculate all the membership functions of fuzzy rank intervals according to all memberships of ϖ set.

$$\varpi = \begin{cases} [1015-1245] & 0 \leq \beta \leq 0.126 \\ [105-1245] & 0.126 \leq \beta \leq 0.296 \\ [1065-1245] & 0.296 \leq \beta \leq 0.374 \\ [112-1245] & 0.374 \leq \beta \leq 0.481 \\ [117-1245] & 0.481 \leq \beta \leq 0.485 \\ [1185-1245] & 0.485 \leq \beta \leq 0.619 \\ [1185-124] & 0.619 \leq \beta \leq 0.807 \\ 124 & 1 \end{cases} \longrightarrow \mu_{\varpi} = \begin{cases} 0 & (-\infty, 1015) \cup (1245, +\infty) \\ 0.126 & [1015-105] \\ 0.296 & [105-1065] \\ 0.374 & [1065-112] \\ 0.481 & [112-117] \\ 0.485 & [117-1185] \\ 0.619 & [124-1245] \\ 0.807 & [1185-124] \\ 1 & 124 \end{cases}$$

- **Seventh Stage:** Calculate Wilcoxon Test statistic (\tilde{U}) and its membership degree $\mu_{\tilde{U}}$
We apply the following relation to calculate Wilcoxon statistic:

$$\tilde{U} = \omega_i - E(\omega) \tag{22}$$

The mean of $E(\omega)$ is calculated as:

$$E(\omega) = \frac{n(N+1)}{2} \quad (23)$$

Then by the placement of different amount of (ϖ) in the relation 22, we estimate Wilcoxon fuzzy statistic interval \tilde{U} and all its memberships $\mu_{\tilde{U}}$ as:

$$\tilde{U} = \begin{cases} [16-39] & 0 \leq \beta \leq 0.126 \\ [19.5-39] & 0.126 \leq \beta \leq 0.296 \\ [21-39] & 0.296 \leq \beta \leq 0.374 \\ [26.5-39] & 0.374 \leq \beta \leq 0.481 \\ [31.5-39] & 0.481 \leq \beta \leq 0.485 \\ [33-39] & 0.485 \leq \beta \leq 0.619 \\ [33-38.5] & 0.619 \leq \beta \leq 0.807 \\ 38.5 & 1 \end{cases} \longrightarrow \mu_{\tilde{U}} = \begin{cases} 0 & (-\infty, 16) \cup (39, +\infty) \\ 0.126 & [16-19.5] \\ 0.296 & [19.5-21] \\ 0.374 & [21-26.5] \\ 0.481 & [26.5-31.5] \\ 0.485 & [31.5-33] \\ 0.619 & 38.5-39] \\ 0.807 & [33-38.5] \\ 1 & 38.5 \end{cases}$$

- **Eighth Chapter:** Calculate significance test level $\tilde{P}(\varpi)$

Now according to the relations 22 and 23 we calculate $\tilde{P}(\varpi)$ for all membership of \tilde{U} :

$$0 \leq \beta \leq 0.126$$

$$\tilde{P}(\varpi)^{\beta} = 2 \times (1 - \phi^{-1}(16 \times \sqrt{\frac{12}{9 \times 9(18+1)}})) = 0.631$$

$$\tilde{P}(\varpi)^{\beta} = 2 \times (1 - \phi^{-1}(19.5 \times \sqrt{\frac{12}{9 \times 9(18+1)}})) = 0.451$$

- **Ninth Stage:** Draw the figures of significance test level

Table 2 shows amounts obtained for \tilde{P} and their maximum membership $\mu_{\tilde{P}}$. Figure 2 indicates not rejected level of H_0 and H_1 at $\alpha = 0.05$.

Table 2: Amounts with maximum degree of membership $\mu_{\tilde{P}}$

\tilde{P}	0.984	0.987	0.865	0.697	0.660	0.641	0.617	0.453
$\mu_{\tilde{P}}$	0.807	1.000	0.481	0.374	0.374	0.296	0.807	0.126

4. Results and Concluding remarks

Results are presented in table 3 and figures 2-9. As an example, figure 2 shows the statistic associated with rules and regulations dimension with its membership degree of 1 located at $H1$. Therefore, the null hypothesis H_0 rejected at 0.95% confidence. This indicates that there is significant difference between perceptions – expectations of study population with respect to rules and regulations dimension of Iran nanotechnology research and development. The same result is true for other dimensions (i.e. idea creation, external relations, investment, social responsibility, human resource, and international cooperation). That indicates there is significant difference between perceptions- expectations with respect to those dimensions of Iran nanotechnology research and development. It should be mentioned that external relations, investment, and international cooperation indicate the highest gap and therefore require a comprehensive planning. Awareness is the only dimension that is not rejected, with membership degree of

1 located at H_0 . So, there is not significant difference between perception-expectations with respect to the dimension of Awareness.

Figure 2 to 9 confirms that rejection or not rejection of hypothesis needs more study of H_0 and H_1 . In this way, (Taheri and Behboodian 2001) suggested an appropriate method. According to this method by comparing area of H_0 and H_1 we can absolutely not reject or reject the given hypothesis. H_0 will be rejected if the area of H_1 is larger than the area of H_0 by using the following relation :

$$\int \pi(\theta|x)H_0(\theta) d\theta < \int \pi(\theta|x)H_1(\theta)d\theta \quad (24)$$

By using this technique the final results of hypothesis tests are suggested in table 3.

Table 3: Final result of hypothesis tests

	Rules and Regulations	Awareness	Idea Creation	External Relations	Investment	Social Responsibility	Human resource	International cooperation
Degree of membership H_0	0.481	1	0.649	0	0	0.443	0.45	0
Degree of membership H_1	1	0.52	1	1	1	1	1	1
Decision making	Rejection H_0	Not Rejection H_0	Rejection H_0	Rejection H_0	Rejection H_0	Rejection H_0	Rejection H_0	Rejection H_0

5. Conclusion

In this study, in order to tackle the issue of ambiguity in measurement tools, we suggested a method based on fuzzy logic. The results of table 3 and figures 2 to 9 indicated that among 8 dimensions of Iran nanotechnology research and development, awareness is just the one with no significant gap, while the highest gap is belong to external relations, investment, and international cooperation. That means “awareness” in the field of nanotechnology is well performed, but a national and comprehensive action plans are required in external relations, investment, and international cooperation in Iran nanotechnology field.

$\mu_{\tilde{P}(\varpi)}$
Level of Significance Membership

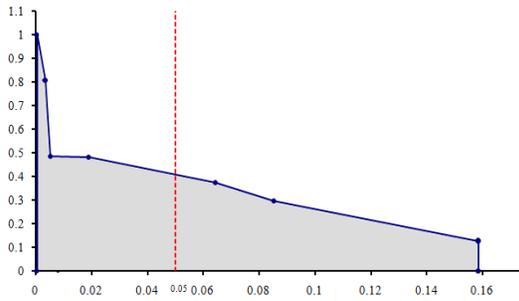


Figure 2: level of significance in hypothesis testing of rules and regulations dimension.

Level of Significance
 $\tilde{P}(\varpi)$

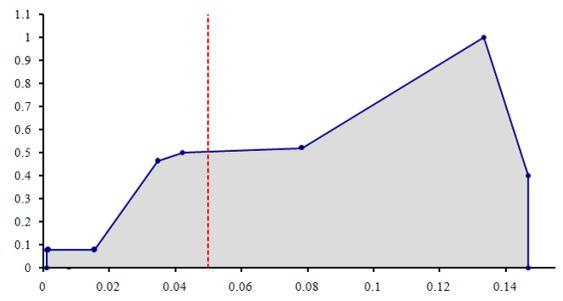


Figure 3: level of significance in hypothesis testing of awerness dimension.

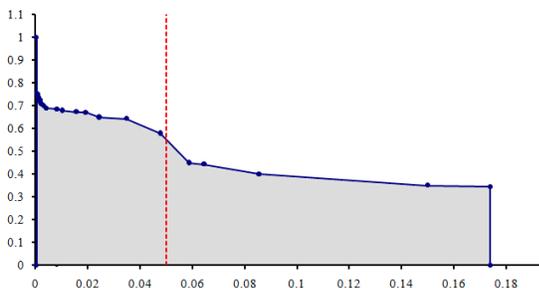


Figure 4: level of significance in hypothesis testing of idea creation dimension.

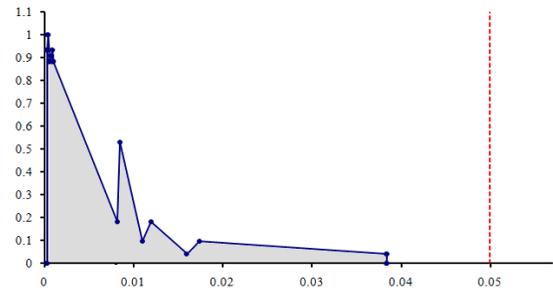


Figure 5: level of significance in hypothesis testing of external relation dimension.

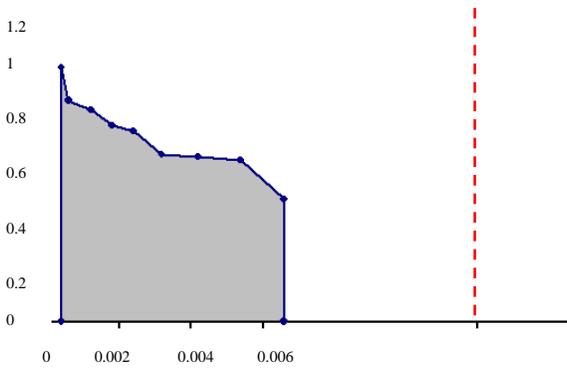


Figure 6: level of significance in hypothesis testing of investment dimension.

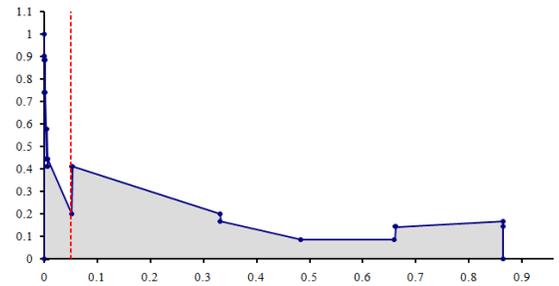


Figure 7: level of significance in hypothesis testing of social responsibility dimension.

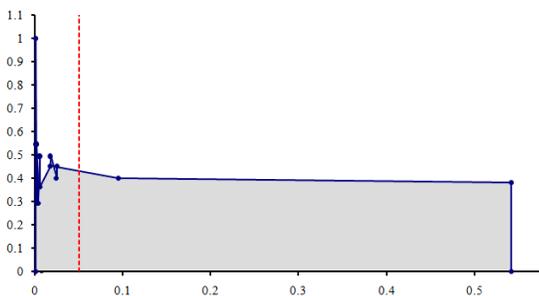


Figure 8: level of significance in hypothesis testing of human resource dimension.

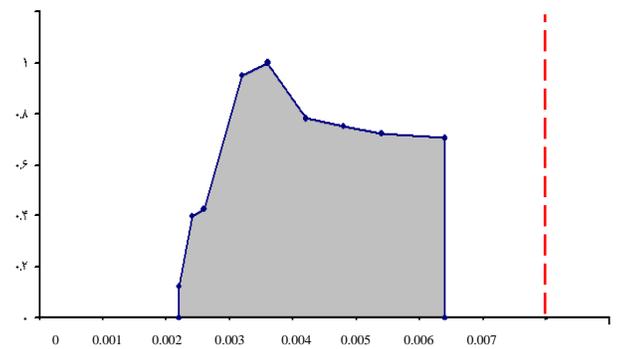


Figure 9: level of significance in hypothesis testing of international cooperation dimension.

Acknowledgment

The author would like to thank A.Rostamkalaei, PhD student in Lancaster University, UK for her numerous helpful suggestions.

References and Citations from Texts

- Beach R, Muhlemann AP, Price DH, Paterson A, Sharp JA. A review of Manufacturing flexibility. *European Journal of Operational Research*. 2000; 122(1):41–57.
- Bordogna, G. and Pasi, G. (1993), "A fuzzy linguistic approach generalising boolean information retrieval: a model and its evaluation", *Information Systems*, Vol. 44, pp. 70–82.
- Chakraborty, D., Optimization in impressive and uncertain environment, Ph.D. Thesis, Dept. of Mathematics, IIT Kharagpur, 1975.
- Ching-Torng, L. Hero, Ch. Po-Young, Ch. (2005). Agility index in the supply chain, *Int. J. Production Economics*.
- Dubois D., Fargier H., Prade H. 1998 Possibilistic likelihood relations, Proc. 7th Int. Conf on Information Processing and Management of Uncertainty (IPMU98), Paris, 1196 -1203.
- Delgado, M., Verdegay, J.L. and Vila, v. (1993), "Linguistic decision making models", *Int. J. Intel. Systems*, Vol. 7, pp. 479–492.
- Denoeoux T, Masson MH, Hebert PA. Nonparametric rank-based statistics and significance tests for fuzzy data. *Fuzzy Sets and Systems*. 2005; 153(1): 1-28.
- D. Dubois and H. Prade. *Possibility Theory: An approach to computerized processing of uncertainty*. Plenum Press, New-York, 1988. S. M. Taheri and J. Behboodan. A bayesian approach to fuzzy hypotheses testing. *Fuzzy Sets and Systems*, 123:39–48, 2001.
- Dyer, J. S., & Sarin, R. K. (1979). Measurable multiattribute value functions. *Operations Research*, 39, 810–822.
- Gerwin, D., (1993). Manufacturing flexibility: A strategic perspective, *Management Science* 39 (4) 395–410.
- Herrera, F.; E. Herrera-Viedma & J.L. Verdegay (1995). "A Sequential Selection Process in Group Decision Making with Linguistic Assessment", *Inform, Sci*. 85, 223
- Herrera, F., Lopez, E., Mendaⁿa, C. and Rodriguez, M. (1999), "A linguistic decision model to suppliers selection in international purchasing", in: L.A. Zadeh, J. Kacprzyk (Eds.), Computing with words in information= intelligent systems 2. Applications, *Physica-Verlag, Schursberg*, pp. 500–524.
- Iran Nanotechnology Initiative Council (2014), monthly Issue, 8th year, No.7, & <http://nano.ir>, <http://statnano.com>, <http://nanoclub.ir>, <http://nanolab.ir>, <http://nanosafety.ir>, <http://econano.ir>, <http://corridor.nano.ir>,
- Law, C.K. (1996), "Using fuzzy numbers in educational grading system", *Fuzzy Sets and Systems*, Vol. 83, pp. 311–323.
- Roco, M.C. (2001). "International strategy for nanotechnology research and development" *Journal of Nanoparticle Research* 3: 353–360.
- Roco, M.C. & W. Bainbridge, eds., 2001, "Societal Implications of Nanoscience and Nanotechnology", *NSF Report, Kluwer Academic Publishers*, Boston, 370 pp.
- Tong, M. & Bonissone (1980). "A Linguistic Approach to Decision Making with Fuzzy Sets", *IEEE Trans. Systems, Man Cyber net*, 10, P.716–723.
- Taheri, S.M. Behboodan, J. A bayesian approach to fuzzy hypotheses testing, *Fuzzy Sets and Systems* 123 (2001) 39–48.
- Zadeh, L.A. (1965). "Fuzzy sets", *Information and Control*, Vol.8, P.338-53.
- Zadeh, L.A., (1975). The concept of linguistic variable and its application to approximate reasoning, *Inform. Sci.* 8,199–249; 8, 310–357; 9 , 43–80.

Biography

Shahla Yassaei has a M.Sc. in Industrial Engineering from Sharif University of Technology, Iran, and MBA degree from Tehran University, Iran. She conducted studies at research center of ICHTO, Iran in the area of Cultural Heritage and Tourism affairs. She is a member of Iranian Fuzzy Society.

Farhad Ghasemi-Tari is currently the Associate Professor in the Department of Industrial Engineering at Sharif University of Technology, Tehran, Iran. He earned his B.S degree in industrial engineering from Sharif University of Technology, and both his M.Sc. and Ph.D. degree in industrial engineering from Texas A&M University, He has published more than 40 papers in the scientific journals and international conferences. His research interests are: Applied Operations Research, Facility Layout, Sequencing and Scheduling, and Combinatorial Optimization. More information is available at :<http://ie.sharif.ir/ie/?p=faculty/ghasemi>.