Intelligent business decision-making research with innovative fuzzy logic system

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Abstract: Conventional business transactions are replaced by intelligent methodologies in decision-making processes especially after the wide-spread use of computer facilities. Elastic decision-making procedures started to emerge since the last two decades, and they deviate from crisp decisions at a certain percentage (up to 30%). Input knowledge and information include numerical and verbal uncertainties (imprecision, vagueness, incompleteness and missing parts). Numerical uncertainty can be treated by well-known non-intelligent methodologies probabilistic, statistical, stochastic, empirical and least square techniques, but the verbal ones are left out the treatment, because computers require numerical data only. Innovative fuzzy logic system provides a domain where mathematical symbolic formulations are not considered at all, but instead, data base logic base is established first and then if necessary numerical data are entered to the fuzzy logic inference system leading to final decision. This paper proposes fuzzy logic decision making modelling, which may be used by different business management experts.

Keywords: business; decision making; fuzzy; innovative; intelligence; knowledge; logical rules; management.

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Biographical notes: Zekâi Şen has graduated from the Technical University of Istanbul in 1971. He received his MSc and PhD degrees from the University of London, Imperial College of Science and Technology, in 1972 and 1974, respectively. He worked at the Technical University of Istanbul, Civil Engineering Faculty, from 1982 to 1995. He then joined the King Abdulaziz University, Faculty of Earth Sciences, Hydrogeology Department, from 1982 to 1992. He is currently at the Technical University of Istanbul. He wrote about 300 SCI papers at different topics as water, hydrogeology, clean energy, climatology, climate change and science philosophy.

1 Introduction

In any social affair including economy, business and commerce, the basic information and general knowledge have uncertain, partially random and mostly fuzzy contents, which derive the decision makers to try and solve their goals partially by uncertainty methodologies such as probability, statistics, stochastic and expert views. Provided that
numerical data are available, the use of the first three methodologies is applicable; if there are also linguistic (verbal) data then their application cannot be validated by these methods. In such a case, recent innovative method of fuzzy inference system (FIS) provides remedial solutions embedded with logical rules (prepositions). The simple principles of this method are active since the creation of men, who have been depending on the rational and logical statements for the objective scientific solutions. However, its fundamentals are given rather recently by Zadeh (1965), who provided a means to treat verbal information for scientific decision makings. Whatever is the domain of problem solution, it cannot be achieved rationally and logically by ready formulations and software, but philosophical and logical ponderous affairs are helpful, which are the basic ingredients of innovative fuzzy logic methodology. Conventional business transactions are replaced by intelligent methodologies in decision-making processes especially after the wide-spread use of computer facilities. Among the non-intelligent methodologies are the probabilistic, statistical, stochastic, rule of thumb and empirical approaches.

Modern societies have increasing trend of social pace and intensity changes as a result of technological developments, innovations in information and communication technologies (ICT) towards globalisation. These points have been emphasised in detail by Synott (2004). The first step should be to acquaintant with the cultural, economic, business environments and bureaucratic affairs of the host country. One of the significant elements in the globalisation is the effect of the imposition of market relations on the social and cultural life in countries formerly protected from such market pressures (Webber et al., 2002). All these affairs include different uncertainty sources, which can be identified by verbal statements and agreements based on fuzzy logic for multi-dialog or consensus. On linguistic information basis the partners should try to optimise each ones benefit, and hence, collective optimisation. Otherwise, crisp logic cannot provide a common basis for each partner. All the mathematical formulations and computer language statements are based on the crisp (two-valued) logic.

Many researchers (Held et al., 1999) suggested globalisation principle referring to the widening and speeding up of global interconnections. Furthermore, Seitz (2002) and Sklair (1999a) explained increasing trends of interdependence between different parts of the world. One of the essential elements of international business is the incorporation of production, trade and capital development across national borders through global corporations (Webber et al., 2002).

Sklair (1999b) categorises globalisation into four main approaches/models: the world-systems, the global culture, the global society, and the global capitalism approaches. The world-systems approach was rooted in the earlier work of Wallerstein (1974), and stresses the division of the world into three hierarchical levels of core countries, semi-peripheral countries and the peripheral countries, in terms of their altering positions in the international division of labour in the capitalist global system. The key issues with this approach, as Wallerstein (1974, 2011) argues, are the unequal economic relations between the core and the peripheral countries in which various policies provide benefits predominantly for the firms in the core countries. The second approach of globalisation – global culture – emphasises the hazards that “a homogenising mass media-based culture poses for national identities” [Sklair, (1999a), p.151]. This idea is based on the very rapid growth and spread of mass media communication, particularly television, and the emergence of what is called ‘the global village’, that has occurred over the last few decades. The notion of ‘the global village’ indicates that “everyone in the world can be exposed to the same images, almost instantaneously” [Sklair, (1999a),
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pp.151–152]. Socio-culturally similar countries tend to have more intensive economic interactions and such a similarity can be in the form of business and management practices, a common or similar language and belief, and cultural characteristics (Johanson and Vahlne, 1977).

Countries regionally, continentally or globally exchange constructive relations and engagements. Effective modern services and information help to make more significant manufactures than before with emergence of innovative methodologies especially in developed and developing countries. International trade and business liquidate money between different countries, which facilitate and triggers further affairs. Concomitantly with the trend toward globalisation, economic restructuring is occurring in the world. Burbules and Torres (2000) indicate economic globalisation occurs in the milieu of a new international division of labour, business and of economic combinations of national economies through which common trade and market agreements emerge.

Restructuring and changes in business decision making models are engines for change in many aspects and sectors of society. The strategic and classical decision-making processes are explained by Janczak (2005). Especially with the pump in of tremendous data in short time requires quick and efficient procession of the coming verbal and numerical information. The classical approaches require data measurements, and therefore, entrance the numerical data to the computer takes some time and perhaps by that time another new data may enter the decision domain. However, in the innovative fuzzy logic modelling, the logical foundations can be established in terms of a set of rules as rule base and then the decision maker can enter such a model with any data for generation of a set of different alternatives. If real data arrives, it is also possible to run the whole of the innovative fuzzy logic model and obtain the corresponding decision variable and accordingly reach at the final decision.

International experience of managers and thus of the firm play an important role in the model choice and construction (Benito and Gripsrud, 1992; Dunning, 1981). Stopford and Wells (1972) mention that most of the decisions depend on the international experience of the company. Likewise, Buckley and Casson (1985) state the probability, i.e. numerical uncertainty of firms help to manage their foreign market involvements. Furthermore, Johanson and Vahlne (1977) assert that uncertainty in international markets is reduced through actual operations in foreign markets, that is experiential knowledge, rather than through the acquisition of objective knowledge. This statement indicates the significance of subjective knowledge rather than objective knowledge in the inter-firm and international affairs. All these boil down to verbal information, which are regarded as uncertain, but they can be expressed by fuzzy logic, after all, there are logical relationships between variables that are important in any firm’s dealings. Hence, the important point for any firm is the accumulation of additional knowledge through consultations and experiences. However, without any logical interconnection between such linguistically knowledge one cannot establish effective modelling, where fuzzy logic systematic modelling comes into view. Accumulation of experience in any firm provides better capabilities for future developments. For instance, Japanese firms have been found to build capabilities through experience gained from overseas markets (Chang, 1995; Lin, 2000). In some studies experience is not considered as a statistically significant factor in entry decisions (Kogut and Singh, 1988; Sharma and Johanson, 1987; Wong and Merrilees, 2009). It is also accepted that a major gap exists in the market entry literature with respect to experience, because experience involves uncertainties in
linguistically available knowledge and information. A firm can reach the most optimum solution by considering not only international but also domestic experience.

It is by now certain that globalisation causes social change, and consequently, the business and economic situations are also affected most often positively. In fact, globalisation is a key to global economic development including business affairs. In the mean-time, countries do not need only a faster rate of economic growth in international trade and business but also a fast and elastic decision making model leading to decisions in the shortest possible time duration.

It is among the main purposes of this paper to provide the theoretical and practical understanding of decision making under uncertainty by use of the innovative fuzzy logic system.

2 Rational and logical thinking

It is mentioned by Şen (2013) that our minds generate uncertain impressions and conceptions by categorising visual environmental reality into fragments for conclusive inferences after labelling each fragment with a ‘word’ such as a name, noun or adjective. Each category has a small portion of the wholeness of reality. Common words help to imagine the same or quite similar objects in our minds. For instance, when one says ‘business’ many understand monetary transactions, exchange of goods or services by money. Each word implies fundamentals of sensations, thoughts and perceptions of some object. Through the words one can imagine distorted conceptual models of reality, which represent perceived human-mind-produced world, which is not a world whose natural evolution has brought us to existence and with which we are linked through an umbilical cord of vital and impossible-to-separate connections (Dimitrov and Korotkich, 2002).

Any type of model starts with foundations of conceptual imagination, design and idea generation fragmentations. Such models can be achieved with logical and rational thinking on the bases of terminological fragmental words and their interrelationships. These meaningful fragmentations are for the exploration of human intellectual mind towards rational thinking. Any supportive knowledge, information, experience, expert view or data help to construct supervised version of conceptual modelling, otherwise pure logical rational thinking are unsupervised alternatives in modelling. Scientists, engineers, economists, politicians and philosophers adapt many distorted conceptual models for predicting and exercising mental power over unfolding dynamics of reality, which are beyond our ability to predict and control without uncertainty.

Most often educationally trained minds confront with dilemma or duality either by selection or rejection its opposite (duality). This is the main trend of mind trainings confined to two-valued (crisp, black and white) logical rational thinking as a first approximation to model the reality. The dualistic nature of rational reasoning component of mind is so strong that mind alone is unable to transcend it; the best it can do is to reconcile the opposites. Hence, the crisp logic has no vagueness, ambiguity, possibility or probability because everything is either absolutely true (white) or absolutely false (black). Classical black-and-white approach in thinking can easily entrap human mind in routines, stereotypes, prejudices and habits that become a source of fuzziness, which eventually makes one incapable for authentic experience.

A set of restrictive assumptions and isolation from the surroundings provides precise (crisp) knowledge rendering the problem into the certainty world by ignoring all
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uncertainty features. Experts or decision makers after taking the final decision multiply the final result by a safety factor depending on ‘over-estimation’ or ‘under-estimation’. Any safety factor accounts for imperfections either in the data or modelling calculations. None of the deterministic formulations is clear from a set of simplifying assumptions, hypothesis, and environmental (laboratory) conditions. The safety factor includes ‘ignorance component’ due to the exclusion of all uncertain information about engineering design.

On the other hand, even today everybody has vague, ambiguous, uncertain, possible and probable concepts and approaches in our daily affairs including business, economy, education, etc. This natural logic is wider and more general than the crisp logic, and therefore, it is labelled as fuzzy thinking when using fuzzy reasoning, where it is possible to accept both the opposites up to some degree of belongingness (Şen, 2013). By following the fuzzy logic-based approach in thinking, one can partially agree with everything the others say and this can easily push expert towards compliance and indecisiveness (Dimitrov and Korotkich, 2002).

For creative research with fruitful and innovative conclusions one is advised to go beyond the established classical logical rules and restrictions no matter how soft (fuzzy) or hard (crisp, binary, deterministic) the concerned phenomena are.

3 Approximate reasoning

After the establishment of fragmented conceptual logical rational thinking leading to preliminary conceptual models, the fragments can be interrelated in a finer manner by reasoning, which is the most important human brain operation that leads to creative ideas, methodologies, algorithms and conclusions in addition to a continuous process of research and development (R&D). Reasoning stage can be reached provided that there is stimulus for the initial driving of mental forces. Ignition of pondering on a phenomenon comes with the physical or mental effects that control the event of concern. These effects trust imaginations about the event and initial geometrical sketches of the imaginations by simple geometries or pieces and connections between them (Şen, 2009). In this manner, the ideas become to crystallise and they are conveyed linguistically to other individuals to get their criticisms, comments, suggestions and support for the betterment of the mental thinking and scientific achievement. Decision making in any problem solution is an essential part of reasoning, because it is an exercise of information inference about observable aspects of a situation based on a set of information, which may include different sources of uncertainty.

The experts who are dealing with linguistic knowledge and information have vague and common sense descriptions of the reasoning. The power of approximate reasoning is to perform reasonable and meaningful operations on concepts that cannot be easily codified using a classical approach. Implementation of the fuzzy logic does not only make the knowledge systems more user friendly, but it also allows programs for justification of better decision improvements.

In order to resurface available knowledge and information approximate reasoning provides decision support and expert systems with powerful mental and rational reasoning that leads to a minimum set of logical rules, which describe the internal structure of interrelationships between the causative (input) and consequent (output) variables. This set of logical rules, which are collectively referred to also as ‘rule base’,
constitute very fundamentals of the fuzzy logic modelling. In reasoning procedure the end products are rule bases that are established by experts in the subject area, and hence, an innovative modelling approach with logical rules provides flexibility for rapid advancements and easier implementation for linguistic problem solutions. During approximate reasoning and its end products as rule base there may not be any numerical data availability. Fuzzy modelling does not include any mathematical formulations or equations, but it reflects the background logical and rational expressions that collectively explain the formulation or equation. Is it possible to derive any equation without approximate reasoning? Of course, the answer is no. The representations of each logical rule by symbols convert the logical system into symbolic logic, which then renders the rule base into equations. Initially, present day equations are based on approximate logic, which is then trashed with a set of restrictive assumptions and put into mathematical symbolic equations.

Unfortunately, in many educational systems all over the world, all of the teaching philosophy, if any, is based on crisp logic without any single concept of uncertainty which restricts the human reasoning abilities. This is especially true for countries, cultures or societies who are trained with symbols and those when they return to their community, the first difficulty is to convey the scientific messages in his/her language, and therefore, in order to avoid such a dilemma the teacher bases the explanation on symbolic logic. This is one of the main reasons why creative thinking and reasoning are missing in many institutions all over the world. The avoidance of such a problem is possible though approximate reasoning where the facts are explained through natural languages.

4 Innovative fuzzy modelling

Since the second half of the 19th century the uncertainty gradient in any domain is modelled either deterministically with its ignorance or probabilistically, statistically, stochastically (Feller, 1967; Box and Jenkins, 1970) and very recently chaotically (Lorenz, 1963) by taking the features of the uncertainty component into modelling consideration. However, all of these methodologies cannot function without numerical data. On the other hand, it is in the nature of business management and administrational affairs that often verbal (non-numerical) data (knowledge, information) play significant role in terms of logical rule bases, which implies that uncertainty has linguistic elements, but many modeller try to convert these information into numerical values so as to be able to use the traditional numerical methodologies for which ready software programs are available almost free of charge. Conversion of linguistic information into crisp numbers causes loss of significant information. When fuzzy logic modelling first appear in the literature (Zadeh, 1965) many classically and traditionally oriented researchers denied its existence and stated that anything that can be done with fuzzy logic, belief functions, upper and lower probabilities, or any other alternative to probability methods can better be done with probability (Lindley, 1987).

Human mental thought models have generally orders of magnitude more complex than man-made systems, which need a radically different kind of mathematics, the mathematics of fuzzy or cloudy quantities which are not describable in terms of probability distributions. Indeed, the need for such mathematics is becoming increasingly apparent even in the realm of inanimate systems, for in most practical cases, the a priori
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Data as well as the criteria by which the performance of a man-made system is judged are far from being precisely specified or having accurately known probability distributions (Zadeh, 1965). All uncertainty methodologies except fuzzy logic modelling are dependent on bivalent (0 and 1) crisp logic fundamental with the exclusion of the middle cases, which are in everyday life play significant role in the business and administration managements, and therefore, probability theory is not a good fit to such realities. Consequently, innovative fuzzy modelling concepts are distinctively different from probability theory with superiority.

Mitcham (1994) has suggested the following strategical steps, which are also very useful prior to the fuzzy logic modelling, because they trigger productive philosophy, which is then supported by rational thinking help to reach better representative models for the phenomenon concerned.

a Conceptual analysis: It is necessary for clarification and correction of terms in theoretical and practical uses, which basically involves logic. The subjectivity, i.e., dependence on personal thoughts is the greatest at the perception stage and as one enters the visualisation domain and conceptual understanding, the subjectivities decrease and at the final stage since the ideas are exposed to other individuals, the objectivity becomes at least logical, but still there remains some uncertainty (vagueness, incompleteness, missing information, etc.), and hence, the final decision remains not crisp but fuzzy. Fuzzy reasoning exists in social, cultural, economic, business, political and even in engineering problems.

b Reflective examination: It provides practice and thought, so as to deepen insight and understanding of extend and to criticise both dimensions of experience. This includes the core areas of philosophy known as ethics, epistemology and metaphysics often with an emphasis on their rational methodologies,

c Experience aspects: These are more global than customarily dealt with by any one discipline. Such aspects may also involve inter-, multi-, trans-, and anti-disciplinary consideration of what is right and good (ethics), knowledge (epistemology), and the structure of reality (metaphysics),

d The practice of a distinctive way of life and thought: It can be taken to be good in itself, with its own unique knowledge of reality. Philosophy in this sense may also be regionalised into the general guiding practices or principles of an individual or group, as when one refers to someone’s personal philosophy or the philosophy of a firm.

The reasoning (philosophy of fuzzy thinking) is based on graded concepts. It is a concept in which everything has a matter of degree, i.e. everything has softness (elasticity). The fuzzy logic theory has been given first in its general form through the early publications of Zadeh (1965). He wanted to generalise the traditional notion of a set and a statement to allow the grades of memberships and truth values, respectively. These efforts are attributed to the complications that arise during physical modelling of real world. These are,

a real situations are not crisp and resolute; hence they cannot be described precisely
the complete description of a real system often would require by far more detailed data than a human being could ever recognise simultaneously, process and comprehend.

The last statement is called by Zadeh as ‘the principle of incompatibility’ which implies that the closer one looks at a real-world problems, the fuzzier become their solution decisions.

Successful decisions can be arrived through the philosophy, which is linguistic in its character. Additionally, it is necessary to consider epistemological aspects of each terminology and question their logical contents in order to arrive at decisions on a consensus basis.

5 Fuzzy rule base technique

Human mind produces logical and rational perspectives of basic concepts and their interrelationships linguistically in a fuzzy domain based on vague knowledge and information. For instance, the most commonly used words are ‘yes’ or ‘no’, but whom from us convert these two basic words into number as 1 and 0, which are crisp (two-valued) elements without any intermediate value? In real daily life do we give answers as ‘yes’ or ‘no’ on completely certainty grounds as 1 and 0 or in our answers are we rather hesitant and prefer ‘yes’ or ‘no’ conceptually in a vague manner, say, a 0.9 or some value between 1 and 0.

Zadeh (1965, 1973) published an article titled ‘fuzzy set theory’ to deal with vagueness of any linguistic type. Unfortunately, for almost ten years his theory did not receive interest among the researchers and Mamdani (1974) demonstrated the applicability of fuzzy inference to automatic steam engine operation. At present all over the world and especially in Japan there is a boom of applications based on fuzzy theory. The fuzzy set concept is an extension of the ordinary crisp sets with membership function (MF) assuming values between zero and one rather than crisp set characteristic value with one (absolute truth) and zero (absolute false) only. In a crisp set any element either belongs to the universal set or not, but in the fuzzy set if the element belongs to a set, it has degree of belongingness that assumes any value between 0 and 1, inclusively [see Figure 1(a)]. Fuzzy theory is a subjective method of quantitative expression sensitivity by a MF, which provides a degree of satisfaction. In Figure 1(b), there are three different fuzzy sets each with different values between 1 and 0, inclusive.

Figure 1 Subsets, (a) crisp (b) fuzzy
Especially in large scale complicated systems such as business it is not possible to obtain sufficiently accurate data due to complexity of the affairs and also hindrance of company information from others. Even experts in business area depend on vagueness about the overall performance of the transactions or about its ingredients. In front of such vague informational data even experts are confronted with information treatment and the only open methodological procedures are probabilistic, statistical and stochastic procedures among which the most widely used ones are simple or multiple regression analyses or cluster analysis, all of which cannot digest linguistic informational data. With all these subjectivity and vagueness, these numerically-based methodologies’ qualitative description might lead to misinterpretations and conclusions.

Verbal information and knowledge data can be treated through the fuzzy set concepts to reach more realistic conclusions on the bases of which the decision-maker can feel comfortable to approve the final decision. Fuzzy logic modelling is beneficial also for the description of the concerned system when the measurements of each factor are available quantitatively. It is possible to render this quantitative information to fuzzy domain through a set of linguistic labels. The business companies’ aspirational fluctuations include uncertainties in the form of vagueness and are therefore suitable for the application of fuzzy theory. In fact, fuzzy concept provides a skilled operator with control performance while looking ahead and avoiding superfluous operations. Hence, through the fuzzy control it is possible to make future predictions.

6 Business and vagueness

Daily perceptions and concepts in many sectors including business are vague, and therefore, may lead to different consequences even in the same environmental, societal and cultural domain. For instance, Hofstede (1980) proposed five mutually inclusive cultural dimensions as uncertainty avoidance, power distance, long-term orientation, individualism, and masculinity, which affect the output production of a company in any business affair.

Especially, in linguistic uncertain domains, innovative fuzzy logic modelling gain importance. As Schumpeter (1942) stated all innovations require some degree of creative destruction, where in the context of modelling destruction is to bring into view the fuzzy logic approach, which covers the expert views in addition to numerical data. On the other hand, disruptive innovations are defined by Christensen (1997) as simple adaptations to existing technologies that appeal to customers who were not attracted to previous products. As Johne (1984) stated there are two phases of product development, namely, the initiation leading to idea generation and the implementation of this idea for marketing. The main purpose of this paper is to present a fuzzy methodology for the idea generation based on five culture factors.

7 Methodological aspects

At every aspect of life one may be confronted with decision-making under the circumstantial conditions, which include certain aspects perhaps at high percentage, but also there uncertain gradients that may appear as main obstacles in final decision confirmation. Social activities require tremendous amount of different activities in many
sectors for planning, design, construction, operation, management and maintenance and each one of these is dependent on other aspects of societal life including economy, business, politics, law, medicine, agriculture and even engineering.

Whatever the involvements logical reasoning has never lost its significance in decision making since time immemorial. In fact, it is the very fundamental basis of scientific and non-scientific thoughts throughout the centuries. It is possible to survive without mathematical, physical or chemical information, but without logic human beings remain as they are without productive thinking for the betterment of the society. Perceptions and concepts can gain importance if they are treated with logical instruments; otherwise they remain frozen without any communicative or associative vividness in the society, which is the case for plant and animal life. Any methodological harmonious solution for the problems at hand is possible first through logical propositions in a set of logical rules, which may then be translated to physical, mathematical, and computer software. Many countries cannot achieve scientific or more importantly technological activities, because their educational systems may be based on crisp logical informational soft or hardware gadgets without reasoning to reach at least to approximate reasoning stages. For instance, the use of computers in almost every aspect of life led business management and each commercial sector to an explosion of software (computer models) for simulation and prediction of possible social and cultural behaviours, economic and political aspects. Subsequently, a host of social models physically, conceptually or in the forms of black-box types have been developed steadily. These models extract necessary information from the available linguistic, and especially, numerical data leading to their future possible prediction replicates. In order to construct a dynamic model for the simulation of any phenomena, say business, it is essential to have a set of linguistic (knowledge, information) and/or numerical data. Given a set of informative sources, the estimation process under uncertainty consists of computing an estimate of the variable concerned at time lead k, the position of which relative to observation period leads to three types of estimations problems (Gelb, 1974).

1. in statistics the estimation of state at any time instant during observation period is referred to as ‘smoothing’ or in mathematics as ‘interpolation’

2. estimation of the state at the final observation time instant is ‘filtering’

3. state variable estimation at a time instant after the final observation, which is referred to in uncertainty domain as ‘prediction’ or in mathematics domain as ‘extrapolation’.

After the model adaptation and determination of its parameters, there comes the stage of ‘identification’, where the suitability of chosen model is tested against available data (numerical or linguistically) at hand. The identification stage includes refinement of the model conceptually or theoretically. In many social, managerial, engineering and business studies reliable predictions become effective after the identification stage.

8 Innovative fuzzy logic models

Most of the records are in linguistic terms, but they are converted to numerical values in some way, for instance as percentages. Some managers employ logistic regression
analysis as his/her systematic model, but it does not relate the input-output variables, instead looks for their statistical significance on a certain significance level. Since the model is statistical, the input variables are used as crisp numerical variables. Wikipedia free dictionary gives the logistic regression as a type of statistical regression analysis, which is used for predicting the outcome of a categorical dependent variable (a dependent variable that can take on a limited number of categories) based on one or more predictor variables. The probabilities describing the possible outcome of a single trial are modelled, as a function of explanatory variables, using a logistic function. It measures the relationship between a categorical dependent variable and usually a continuous independent variable (or several), by converting the dependent variable to probability scores. The term ‘categorical variable’ is the most basic essence of the fuzzy logic (Zadeh, 1965; Şen, 2009) where each variable is categorised into a set of sub-set numbers (recommended number 3–7), which are referred to as the fuzzy sets or MFs (Ross, 1997).

In fuzzy modelling system not only dependent variables but also independent variables are also categorised into a number of fuzzy sets. The main purpose of this paper is to provide basic modelling approach of the fuzzy logic system in order to infer results from linguistic data, which are rather blurred, vague, uncertain, incomplete and dubious.

Experience is the most important human expertise to gain knowledge and information in addition to ‘know-how’ in any affair through discussions, critics, debates and questioning. This leads to accumulation of linguistically pieces of information that must be combined in an expert manner to infer the deductive conclusions. Experience can be gained by time gradually about foreign country culture, commercial affairs, human relations, economical system and political stability and other factors. Experts on such transactions become wanted personnel in the international firm activities. Almost all information and knowledge are in terms of verbal logical statements, which provide partial and at times holistic relationships between internal and external factors.

The fragments and categories made out of perceptions – sensations and thoughts, serves to provide partial, and therefore, distorted conceptual models of reality, which are abundant in scientists, engineers, economists, business enterprises, politicians and philosophers, and consequently, they may adapt different distorted models for prediction and control over the unfolding dynamics of reality. Although it is known that complex dynamics of reality are beyond human ability to predict and control, one can ‘do his/her best’ to make the best possible modelling approach to the problem. The applications of this kind of models have made both nature and social reality vulnerable; this is clearly demonstrated by today’s ecological disasters and continual worsening of socio-economic conditions for the largest and ever-increasing part of society.

Mind can hardly move beyond duality – it either selects something while rejecting its opposite (as in black-and-white thinking when using binary logic) or accepts both the opposites up to some degree (as in fuzzy thinking when using fuzzy or probabilistic reasoning). The dualistic nature of rational approximate reasoning component of mind is so strong that mind alone is unable to transcend it; the best it can do is to reconcile the opposites.

Following the black-and-white approach in thinking (‘either A or not-A’), one can be easily entrapped in routines, stereotypes, prejudices and habits that become a source of fuzziness, which eventually makes one incapable for authentic experience. Following the fuzzy logic-based approach in thinking (‘both A and not-A’ up to some degree), one agrees with everything the others say and this can easily push one towards compliance and indecisiveness. When everybody is right, the uncritical acceptance of the fuzziness
accompanying other people’s thoughts makes it hard for one to generate his/her own creative ideas. Even though the domain of information and modelling may be rather fuzzy but the final conclusions can be turned to crisp answers by defuzzification of the final fuzzy decision set. Fortunately, in the applications of fuzzy logic a procedure called ‘defuzzification’ is used to keep the degree of decisiveness of a soft computing system at an effective operational level. In the process of understanding, it is advised to beyond crisp logical rules and restrictive assumptions so as to have soft (fuzzy) decision solutions.

In general, a business model can be developed as an abstract conceptual description of soft structure for final management and decision making purposes in which logically categorised variables are available including cooperational, financial, social and commercial interrelationships. This model provides a common base for products, services, sales towards strategic aims and scope of an establishment or a company. A business model is the homeledge of logical, rational and approximate reasoning composition, which guides in the best possible way production, sales, delivers, costumers, market and economics in the framework social, cultural, local and international environmental circumstances. A successful business model with its conceptual, theoretical and practical aspects serves as a useful instrument for formal, informal, scenario and favourable or unfavourable descriptions for the optimum business affair. Further extensions to this design logic emphasise the use of narrative or coherence in business model descriptions as mechanisms by which entrepreneurs create extraordinarily successful growth firms (George and Bock, 2012).

The principle formal structure of a business model can be represented as in Figure 2 with a set of causative (input, antecedent) and a single result (output, consequent) variable (Şen, 2014). In the figure there are five antecedent variables which can be of any number. In any empirical model internal and external factors are, in fact, input and output set variables where output variable(s) should be expressed in terms of input factors through a systematic model.

The structure in Figure 2 can be innovative fuzzy logic model if the inputs and/or output variables are expressed in terms of verbal expressions as sub-categories of each variable. For instance, trade variable can be partitioned into a number of mutually inclusive sets as in Figure 3.

**Figure 2** Fuzzy business models

![Fuzzy business model diagram](source)
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Figure 3 Variable fuzzy sets

![Membership degree (MD)](image)

Notes: VS: very small; S: small; M: medium; B: big; VB: very big.

Each logical proposition with its antecedent part is composed of various sub-classifications of the input factors leading to consequent part and the inference system is expected to produce linguistically qualified outputs. It is possible to establish a qualitative model through logical propositions, which are also called as rules, where a set of rules constitute rule base for the phenomenon under consideration.

Consideration of what have been explained above may help to establish a fuzzy business model as in Figure 2, where there are five input dimensions that cause collectively to the output quality and quantity.

Figure 4 Fuzzy rule bases

<table>
<thead>
<tr>
<th>Rule</th>
<th>IF UA is “L” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN .......... OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>R001</td>
<td>IF UA is “L” AND PD is “M” AND LT is “L” AND IC is “L” AND M-F is “M” THEN ..........</td>
</tr>
<tr>
<td>R002</td>
<td>IF UA is “L” AND PD is “H” AND LT is “L” AND IC is “L” AND M-F is “H” THEN ..........</td>
</tr>
<tr>
<td>R003</td>
<td>IF UA is “L” AND PD is “H” AND LT is “L” AND IC is “L” AND M-F is “H” THEN ..........</td>
</tr>
<tr>
<td>R004</td>
<td>IF UA is “L” AND PD is “M” AND LT is “M” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R005</td>
<td>IF UA is “L” AND PD is “M” AND LT is “M” AND IC is “L” AND M-F is “M” THEN ..........</td>
</tr>
<tr>
<td>R006</td>
<td>IF UA is “L” AND PD is “H” AND LT is “M” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R007</td>
<td>IF UA is “L” AND PD is “H” AND LT is “M” AND IC is “L” AND M-F is “M” THEN ..........</td>
</tr>
<tr>
<td>R008</td>
<td>IF UA is “L” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R009</td>
<td>IF UA is “H” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R241</td>
<td>IF UA is “H” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R242</td>
<td>IF UA is “H” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
<tr>
<td>R243</td>
<td>IF UA is “L” AND PD is “L” AND LT is “L” AND IC is “L” AND M-F is “L” THEN ..........</td>
</tr>
</tbody>
</table>
Şen (2014) has given a detailed explanation about the fuzzy logic modelling in different aspects of life like commercial, economic, governmental decision-making processes. The content of that article is repeated partially in the following sequel. Since in each input variable there are three fuzzy sub-sets, the total alternative number is equal to \(3^5 = 243\) rules, where each input variable fuzzy sub-set is attached with other input fuzzy sub-sets through logical ANDings and among the rules ORing connectives are valid. If ‘low’, ‘medium’ and ‘high’ sub-sets are represented shortly as ‘L’, ‘M’ and ‘H’ then one can write all of the 243 rules mechanically as in Figure 4.

Many of these rules may not be logical, and therefore, they can be eliminated from the list according to fuzzy and approximate reasoning by two sets of specialists as,

1. The person who is interested in the problem can go through each one of these rules and make his/her assessment for each line, whether the statement is logically valid or not. If not, then the statement must be excluded from the rule base.

2. After the first step elimination, the remaining rules can be given to several other experts so as to take their independent opinion about the validity of each rule logically and for further possible eliminations from the rule base.

After these two steps in business management one can reach to a consensus among different experts who are interested in the problem solution. In this manner, without any numerical data availability, experts can construct the model fundamentals linguistically. The final rule base including the common view of experts is now ready for the allocation of the consequent part of each statement. The completion of the consequent parts (dotted parts after then in the aforementioned rule base) is necessary prior to final decision making. After the completion of logically valid rules and their consequent part the expert rule base is then ready for inference leading to decision. For this purpose, numerical or fuzzy numerical data are not required, which will fire the antecedent parts of some rules in the rule base and then a transition from the consequent part to the consequent part will provide the outputs of each rule. Figure 5 provides systematic execution exposition in any FIS modelling.

**Figure 5** General FIS

![General FIS Diagram](source: Şen (2010))
In Mamdani FIS there are two similar inference systems with crisp and fuzzy inputs. First the crisp input Mamdani FIS will be explained. The first step in such an approach necessitates the rule base and in Figure 6 for simple explanation the fuzzy rule triggering idea is exemplified with two rules as in Figure 6.

Available data values are entered on the horizontal axis with $X_1$ and $Y_1$ data pair and they trigger among many rules these two rules. Since each linguistic variable fuzzy set is related to another one through ‘ANDing’ according to fuzzy set operators it is necessary to take the minimum MD among the two which are $d_1$ and $d_2$ in the first rule and $d_3$ and $d_4$ in the other. ‘ANDing’ means minimisation and therefore the minimum MDs are transferred to the output section of the rule base. Accordingly the transfer MDs are $d_2$ and $d_4$, respectively. Transition of $d_2$ on the consequent part of the rule now depicts MD on the vertical axis and then onwards the corresponding fuzzy set is truncated into two parts, as triangle above and trapezium below. Since the minimisation of the MDs is adopted then the truncated trapezium is considered as the output fuzzy set on the consequent part of the first rule. It is shown in shadow in Figure 6. This trapezium is although a fuzzy set but it is not formal and normal in the sense that there is no element with MD equal to 1. Hence, in the inference systems the consequent part fuzzy sets are not standardised to have the formal fuzzy set property. Similarly, for the second rule at $d_4$ MD level there is also another trapezium but they do not have the same base. The first one is the remnant of ‘low’ whereas the other one is the ‘high’ fuzzy set truncations. Hence the consequent part inferences are available individually.

After this operation the antecedent parts of each rule are not needed any more and now the question is how to combine the triggered rule consequent parts together. The rules are connected by ‘ORing’ in the rule base and in fuzzy set terminology it corresponds to maximisation of the consequent parts. Maximisation of then two
consequent truncated trapeziums lead to overlapping of the two as shown on the right hand side bottom of Figure 6. If there were more than two rules fired then the final combination of the consequent parts will appear in an irregular shape of non-normal fuzzy set. This inference system is referred to as the min-max operation because first minimisation (‘ANDing’) and then maximisation (‘ORing’).

In order to use the fuzzy modelling in business management the source of data is mostly in the forms of questionnaire, which are useful in obtaining basic verbal information from experts like business practitioners, university staff members, who may have knowledge and information about the concerned business. Expert views can be transformed to numbers between 0 and 100 about each variable for finding the MD of each variable.

Logistic regression is used to estimate the effects of control, culture, intensity of competition, business experience, and industry type on the probability of selecting export-entry mode over non-export entry mode. Logistic regression is recommended when the dependent variable is binary, the independent variables are both categorical and continuous, and the assumption of multivariate normality has not been met (Hair et al., 1998). Two categories of the dependent variable is similar to crisp logic as explained above where there are two mutually exclusive alternatives as export and non-export. In fuzzy modelling such two modes can be fuzzified as in Figure 7, where EE and NE are abbreviations for export and non-export.

**Figure 7** Export variable fuzzification

It is also possible to increase the number of fuzzy subsets to three or more, for instance, in case of three one can also include the medium export mode between the export and non-export alternatives. This figure provides the output of the fuzzy model whereas five inputs, control, culture, intensity of competition, business experience, and industry type play the role of input variables similar to the general fuzzy model in Figure 3. Accordingly the rule base and the fuzzy inference procedures can be applied for final decision making.

9 Conclusions and recommendations

With the facilities of information technological developments during the last two decades the modelling, simulation and prediction of uncertain social, economic, business, political and management events took another direction with the possibility of uncertainty treatments through logical and rational approximate reasoning even though the available data may be in the form of verbal statements that provide interrelationships between the causative and consequent variables. This became possible since three decades due to the
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suggestion of fuzzy sets to account for the linguistic type of vagueness, imprecision, incompleteness, uncertainty, missing partial information. Fuzzy models include a set of linguistic rules in the form of rule base and then fuzzy inference mechanism for the final decision, which may also be uncertain to a certain extent, but can be defuzzified for crisp decision makings.

Intelligent decision making is essential in many aspects of life and especially business affairs with their uncertain information bases are prone to misleading final decisions, if the embedded uncertainties are not taken into consideration by means of convenient models. Since in many transactions such as business there are vague, imprecise, missing and linguistically uncertain ingredients their treatments must be achieved in such a way that not only numerical but also verbal knowledge, information, experience and expert views are also digested in the same systematic model. This paper presents the basics of such a model in terms of innovative fuzzy logic approach where rather not the crisp sets but fuzzy sets play the major role for each modelling component (input or output) and their logical harmonious, rational and logical interrelationships as a set of logic rules, which is referred to as the rule base. It is emphasised in this article that whatever the decision making objectives it is a must to reach at the rule base by approximate reasoning, and hence, deduce the relevant logical internal structure of the phenomenon dealt with as the decision-making in business affairs, which is given as an application. The proposition of this paper does not deny completely the deterministic model usages but provides an additional domain by introducing innovative fuzzy logic modelling for fruitful decision making. It should be noticed that the concept of globalisation through foreign investment and international business cannot be simply applied to any developing market; it requires a thorough understanding of the local environmental circumstances, such as business environment and the government policies to optimise the possibility of business success for firm and beneficial final decision making.

The main conclusion of the paper is a suggestion to make decisions in the business domain by using FIS, which digests verbal information. This paper provides a common basis towards fuzzy decision-making orientation. It is hoped that in the future such soft and intelligent decision-making procedures will be cared for better conclusions. The commercialisation of the fuzzy logic methodological applications is not yet widely spread. However, in the near future the fuzzy decision-making procedures are expected to be used by many companies.

References


