

# The Factors Affecting Minorities' Satisfaction of Health Care Service Utilizing Fuzzy Rule Based Systems

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## ABSTRACT

The aim of the study is to determine factors in health communication, when minorities are serviced in a language different from their mother tongue. Health care service satisfaction when doctor and patient speaking the common language or the mother tongue is an important area of investigation. On the other hand, when either of them speaking different languages, namely, generally patients in the minority position speaking a language different from the one doctor speaks, health communication becomes cumbersome for both sides resulting in low level of health care service satisfaction leading to ultimately wide range of complaints from minority patients. How attributes playing roles on health care service satisfaction in minority patients by modeling the relationship is conducted. Therefore, single attributes and interrelated ones are determined. The data is collected using a questionnaire form based on stratified sampling method, 387 participants are included in the analysis. Questionnaires were distributed among minorities living in Vienna area. The factors that are impact on health care service satisfaction are extracted by factor analysis. Questionnaire data collected as verbal statements representing the subjective evaluations of participants transformed into mathematical functions using fuzzy set theory enables to model attributes affecting health care service satisfaction using fuzzy logic called fuzzy rule based systems. Modeling tool called Fuzzy Rule Based Systems is a mathematical model in order to explain which single factors and/or interrelated ones having impact on health care service satisfaction are determined by employing fuzzy set theory and fuzzy logic, which are the components of the mentioned mathematical model. The findings suggest that the first expectation by minority patients from doctors is to respect to their cultural differences. If it is met at the first glance, then health care service satisfaction tends to increase with the positive effects of other attributes. If not, health care service satisfaction stays at lower with no other attributes playing major roles. According to the findings of the study, other attributes or interrelated ones play significant roles on the health care service satisfaction when they are singly evaluated, which lead to comprehend not only single attributes but also interrelated ones by minorities.

**Keywords:** Health care service satisfaction, health communication, fuzzy rule base systems, minorities, fuzzy set theory

## Azınlıkların Sağlık Hizmetlerinden Memnuniyetlerini Etkileyen Faktörlerin Bulanık Kural Tabanlı Sistem ile Modellenmesi

### ÖZ

Çalışmanın amacı, azınlıkların anadillerinin dışında diğer bir dilde sağlık hizmeti almaları durumunda karşılaştıkları sağlık iletişimi sorunlarının tespitidir. Sağlık hizmetlerinden memnuniyet hem doktor hem de hastanın ortak dili veya anadili konuştukları durumda önemli bir araştırma alanıdır. Hastanın azınlık olması durumunda, yani, doktorun konuştuğu dilden farklı bir dil konuşuyor olması durumunda, sağlık iletişimi istenilen düzeyde olmadığından hasta şikâyeti artmakta ve sağlık hizmetlerinden memnuniyet olumsuz yönde etkilenmektedir. Azınlıkların sağlık hizmetlerinden

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*memnuniyetini etkileyen faktörlerin neler olduğu ve nasıl bir etkiye ve etkileşimlere sahip oldukları önemli bir araştırma konusudur. Çalışmada tabakalı örnekleme yöntemi ile Viyana'daki göçmen nüfus ile orantılı olacak şekilde örnekleme gözlemler alınmıştır. Veri toplama aracı olarak çoktan seçmeli anket formu kullanılmıştır, toplamda 387 katılımcı çalışmada yer almıştır. Bu çalışmada, anketin gerçekleştirildiği Viyana bölgesindeki azınlıklardan değerlendirmeleri toplanmış ve faktör analizi yapılarak faktörler belirlenmiştir. Bu değerlendirmeler özeldir ve içinde belirsizlik bulunmaktadır. Bu tür belirsizlik istatistiksel veri analizi ve modellenmesinde karşılaşılan ve olasılık teorisi ile ölçülen belirsizlikten farklıdır. Bu tür belirsizliğin ölçülmesi ve modellenmesi için yazında yer alan Bulanık Küme Teorisi ve Bulanık Kural Temelli Modelleme kullanılacaktır. Bu model ile sağlık hizmetlerinden memnuniyeti etkileyen tekil faktörler ve etkileşimli faktörler belirlenmiştir. Çalışma sonuçlarına göre, en çarpıcı bulgu azınlıkların kültürel farklılıklara saygı gösterilmesini beklemesidir. Eğer bu ilk başta sağlanırsa, diğer faktörlerin etkisi artırıcı yönde etki ederek, azınlıkların sağlık hizmetlerinden memnuniyetinde hızla yukarı yönde etkiye sebep olduğu bulunmuştur. Eğer bu durum ilk başta sağlanamazsa veya düşük düzeyde görülürse, diğer faktörlerin etkisi de sınırlı kaldığı araştırma sonucunda bulunmuştur.*

**Anahtar Kelimeler:** Sağlık hizmetlerinden memnuniyet, sağlık iletişimi, bulanık kural temelli modelleme, azınlıklar, bulanık küme teorisi

## I. INTRODUCTION

The ultimate objective of health care service is to improve the patient's health and medical care, improving life quality of the patients. Success in doctor-patient communication is the most critical factor that it is the kick-start of all the health care services. Miscommunication that may occur between doctor and patient can result in outcomes that seriously jeopardize efforts in maintaining and improving patients' life quality and even saving patients' lives. Improved communication in health care is today an objective to strive for. Health communication is a precondition for appropriate care and treatment in health care.

In the health care communication setting, doctors as well as patients have to communicate with a variety of parties. Health communication literature generally includes the doctor-patient relationship, diagnoses, explaining risk, and providing education and information about health conditions (Roter, Hall 2006). It is a known fact that an effective communication between doctors and their patients is essential to successful diagnosis, treatments and the improved health care service satisfaction by patients.

This paper addresses the doctor-patient communication, ignoring all other parties supporting health care services. Determining the role of attributes and the effects of them on Health Care Service Satisfaction is investigated for minorities.

Doctors are the prominent health care provider communicating with the patient, followed by the nurses, nursing assistants, and medical secretaries (Nørgaard et al. 2012). From a doctor's point of view communicating with the patients is dependent on knowing enough about their health condition related to their illness. However, from a patient's point of view communication with the doctor is an emotional state. Doctor talks about the benefits, costs, and risks of different medications, but patients just want to hear he/she will be okay after the treatment.

Although doctors tend to blame patients and patients tend to blame doctors, due to some important issues such as poor literacy and language skills of the patients, patients' limited ability to comprehend numeric information, many doctor-patient discussions occur within less than 15 minutes causing high emotional levels for both parties. The lack of training and skills on health communication issues between doctors and patients for effective problem

solving are main reasons for poor doctor-patient communication (Gregory et al. 2011). In doctor-patient communication, power and decision-making responsibility are not shared. They rest on the shoulders of the doctors; leading doctors tend to limit their communication with patients because of the presumed leading role of doctors in decision-making. The patient quickly accepts a recessive role. Then patients may feel that it is inappropriate for them to participate in the consultation.

It is obvious that a patient in pain may have communication problems with the doctor, but for an immigrant, he is not only acutely ill, but also he is trying to communicate in an unfamiliar environment with health care providers who may not know how to communicate with them. Consequently, minorities are at the risk of discrimination in health care services setting causing to receive suboptimal healthcare, which results in poorer long-term health outcomes. Researchers found significant differences in the quality of doctor-patient communication among minorities and local patients because doctors were more verbally dominant and tended to be less patient centered in their approach with minorities (Blendon et al. 1995; Johnson et al. 2004). Minority patients, especially those not proficient with host country language, are less likely to engender empathic responses from doctors, less likely to establish rapport with doctors, less likely to receive sufficient information, and less likely to be encouraged to participate in medical decision making, all been linked to patient satisfaction (Ferguson, Candib 2002).

Good doctor patient communication has been shown to have a positive impact on a number of health outcomes. Some beneficiary results are reduction in emotional distress in patients, better emotional and physical health, higher symptom resolution, and better control of chronic diseases that included better blood pressure, blood glucose and pain control, the degree of patient-centered communication was associated with less discomfort, less concern and better mental health in patients. Effective doctor patient communication is shown to be highly correlated with patient satisfaction with health care services (Greenfield et al.1985, 1988; Stewart 1995; Rosenberg et al. 1997; Henrdon, Pollick 2002; Roter et al. 2002; Maguire, Pitceathly 2002; Wong, Lee 2006).

Health communication is an unexceptional problem as the doctors speak a more scientific language called Latin. That is an inappropriate common communication medium. The literature researching how healthcare providers and people in general should communicate is important. Moreover, the health communication literature includes communicating with the elders, patients with poor literacy, and people admitted into acute hospitals that have a different language and/or cultural background from their healthcare providers (Arthur 1995; Plunkett, Quine 1996; Park, Song 2005; Ishikawa, Kiuchi 2010).

Language preference is significantly associated with how minorities perceive their healthcare providers' communication and facilitation of patient autonomy in making healthcare decisions. Host country language speaking responders are reported that their healthcare provider "always" listens to them carefully, explaining things so that they understand, spend enough time with them, ask them to help make healthcare decisions, and show respect for treatment (Wallace et al. 2009). However, when it comes complicated issues dealing with culture, doctors' initial conversation for gathering basic information related to the patient history becomes insufficient.

Health care system has a "culture". Culture can be defined as sets or systems of historical, learned, and/or human-made beliefs, values, behaviors, and norms (Hofstede 2001). The values, behaviors, and norms that constitute medical culture are evident in traditions that are passed through generations of medical education and training. In fact, medicine adheres to strong tradition and hierarchy. Examples of medical culture include language (extensive

abbreviations and acronyms), clothing (white coats and scrubs), and norms of behavior (adherence to hierarchical structure and demonstrations of respect as suggested in the Hippocratic Oath) (Kirschbaum 2012). Even for a local patient, communication with the doctor is a challenge, as doctor-patient communication is a clash/encounter of two different cultures, immigrants may face more serious problems in health care services as individualistic values and practices are involved in health communication. However, few researchers investigated the doctor-patient relationship that addresses the influence of cultural difference between doctors and patients in health communication setting (Ferguson, Candib 2002). Thus, the study aims at filling the gap in the health communication literature by researching factors affecting doctor-patient communication within minority point of view. The data collected from 387 participants are analyzed using Fuzzy Rule Based Systems.

The organization of the paper is as follows: In Section 2, the data is presented and its preparation for further analysis is explained under the title of Methodology. Section 3 covers what Fuzzy Logic and Fuzzy Rule Based Systems (FRBS) with fundamental notions and definitions mean and how they are implemented in the light of our data set giving some step by step illustrative information under the title of Introduction to Fuzzy set and fuzzy logic. The Section 4 is for Results and the final section finishes with discussion.

## **II. METHODOLOGY**

The study aims to research factors having effect on minority's healthcare service satisfaction using Fuzzy Rule Based System (FRBS). The first phase of the study, descriptive statistics and explanatory factor analysis is used for further analysis, which is called FRBS. The field study is performed in Vienna, inhabiting nearly 500.000 minorities in a 1.700.000 total population (Statistik Austria, 2011). Although, Vienna is a metropolitan area where minorities live all over the world, the study focuses on minorities mainly from Germany, the Balkans and Turkey. Those people account for the 2/3 of the total minorities in Vienna. The minority distinction is made based on the definition of Monitoring Integration Wien research. The questionnaire items are adopted from the Migrant-Friendliness Questionnaire (MFQ) and Migrant Friendliness Quality Questionnaire (MFQQ). After items are discussed and consensus on them are reached by a group of researchers consisting of two doctorate students and two academicians, they are translated to the languages of German, Serbian, Croatian, Bosnian, Macedonian and Turkish that account for % 12,13, %29,81, %2,27, %9,97, %2,69 and %19,43 of the minority population living in Vienna respectively. Questionnaire consists of 49 items where 32 of them are designed as Likert type, 15 of them are demographic and 2 of them are open end items. Pre-test is performed to 51 participants to define possible problems. This type data collecting is called convince sampling, which is one of the non-probability sampling method. Pre-test questionnaire is tested for validity and reliability, and correlation analysis is performed, and miss-understood items are removed. 29 Likert type questions and 14 demographic ones remain after elimination. In order to proportionally represent each minority group in our sampling, Multinomial scheme is employed resulting in a total number of 387 participants taking part in the study. Questionnaires are distributed through non-governmental organizations.

Exploratory factor analysis with principal component method and varimax rotation is performed. Factor Analysis (FA) is run in order to determine how many hypothetical dimensions can be obtained from the responses. Likert-type scores between 1 through 5 assigned to verbal answers of questions by respondents are used. Items consisting of questionnaire are grouped under the hypothetical dimensions after running FA. Those grouped items composing each hypothetical dimension is titled and abbreviated such as Doctor-Patient Communication (DPC), Language Problem (LP), Minority Status (MS), Cultural Differences (CD) and Health Care Service Satisfaction (HSS). Those variables are

the ones that will be used in FRBS. The first four of them are selected as input variables and the last one is output variable.

### III. INTRODUCTION TO FUZZY SET AND FUZZY LOGIC

Uncertainty has many aspects in data analysis and modeling. One of the aspects is probability theory where whole statistics theory almost depends on. However, when other types of uncertainties emerge in data structures, traditional approaches produce unreliable results. Fuzzy Set Theory (FST) introduced by Zadeh in mid-60's has dealt with uncertainty inherited in natural languages which is called imprecision in terms of uncertainty terminology (Zadeh; 1975a, 1975b, 1975c). Engineering fields and mathematics are the first disciplines employing fuzzy set theory (FST) based implementations. However, disciplines in social science have not paid attention to FST even though the data they deal with is very suitable.

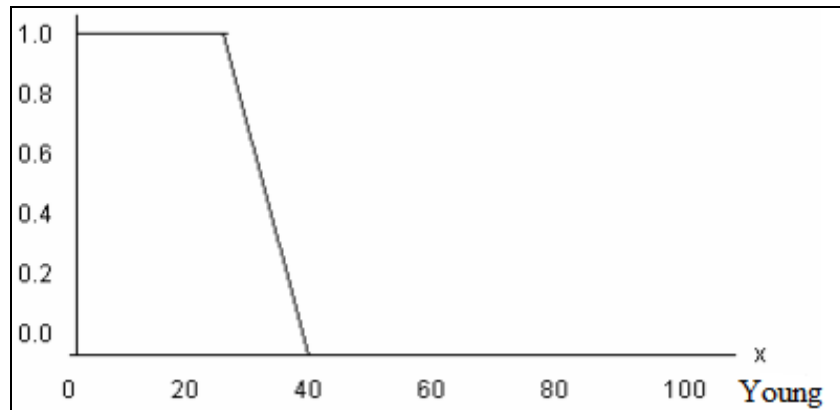
In this section, a wide coverage from fuzzy set and fuzzy logic to implementation of them is presented in order to provide informative and comprehensive content. Throughout this section the fundamental notions, concepts and definitions are taken from the reference books (Dubois, Prade 1980; Nguyen, Walker 1998). We begin with an example which will be the starting point towards the explanation of fuzzy set theory. for example, the term "rich" is understandable for almost anyone. Also it is true for other terms such as "poor", "hot", "big" and so on. Actually when they are closely examined in terms of the values assigned to them by persons, the way they are understood is completely different. This difference cannot be seen in daily life usage when persons use them. However, when persons are asked to assign values to those terms, the difference in perception can be easily observed. While \$40000 annual income is a certain amount for a person to be rich, \$80000 annual income might be a partially enough amount for a person to declare himself as a rich. Actually "rich" is a set whose elements are numbers assigned by persons in terms of perception about how much money representing of being rich. Also the left and right boundaries of this set are not sharp since we cannot determine what is either the least value or the biggest value of this set. The values on the bigger side on the boundaries of this set might be an element of another set called "very rich". This imprecision brings a new important notion called membership degree which is characterized as a measure of belonging to the set. Before continuing with formal definitions, an example provided by Zadeh is presented here in order to give illustration (Zadeh 1965).

For example, the term "young" is concern. How can anyone assign a value to this linguistic variable? Its answers change from person to person. Therefore, uncertainty stemming from natural language is obvious. In order to manipulate this linguistic term, a mathematical function is needed for representation of it. Therefore, a function is given for a term "young" by Zadeh as follows:

$$\mu_{Young} = \begin{cases} 1, & \text{if } x \leq 25 \\ \frac{1}{1 + (\frac{x-5}{25})^2}, & \text{if } x > 25 \end{cases}$$

(1)

Its graph is displayed below



**Figure 1. Membership Degrees**

A criticism can be directed to the subjectively chosen function for the linguistic variable “young”. However, the subjectivity can be easily overcome by collecting as many opinions as possible to reach consensus on the term “young”. Therefore, more representative function can be generated based on consensus. In general, this consensus is achieved by expert knowledge. In this example, “age” is a linguistic variable whose value is “young” which is represented by a membership function given above. Another criticism can be directed to the linguistic variable “age” which is supposed to be numerical variable. Despite of the fact that age is a numerical variable, its usage as a categorical variable in statistics is possible. Hence, any variable can be transformed into linguistic variable by choosing suitable membership functions representing it. All definitions regarding the development of FRBS including fuzzy set, binary logic, and fuzzy logic are provided below. The references related to this subsection are taken from (Dubois, Prade 1980; Nguyen, Walker 2000)

**Definition 1** Fuzzy set A is a class of elements having membership grades characterized by a membership function assigning each object a grade of membership degree changing between 0 and 1.

**Definition 2** A fuzzy set is a function defined by membership function from the universal set U into closed interval [0,1] defined by

$$\mu_A(u): U \rightarrow [0,1]$$

Where U is the set on which the linguistic term A is defined and u is the generic element of set U

In real life applications, instead of using theoretically defined set U, real number set R is more appropriate to be used. For example, when the term “rich” is concerned, it is quite clear that the set has elements taking values from positive values of R. Then a more applicable definition is given below.

**Definition 3** A fuzzy set is a function characterized by membership function from R into closed interval [0, 1] defined by

$$\mu_A(x): R \rightarrow [0,1]$$

Where R is the set on which the linguistic term A is defined and x is the generic element of R.

When a fuzzy set A is defined on real numbers R, it is called a fuzzy quantity.

Definition 4 A fuzzy quantity is a fuzzy set defined on real numbers is a function from R into closed interval [0,1] denoted by

$$\mu_A(x):R \rightarrow [0,1]$$

Definition 5 Set operators defined on classic sets such as intersection, union and negation can be extended to fuzzy sets as follows

$$\begin{aligned} (\mu_A \vee \mu_B)(x) &= \max\{\mu_A(x), \mu_B(x)\} \\ (\mu_A \wedge \mu_B)(x) &= \min\{\mu_A(x), \mu_B(x)\} \\ \mu'_A(x) &= 1 - \mu_A(x) \end{aligned}$$

Definition 6  $\alpha$ -cut of a fuzzy set A is a set defined as follows:

$$A_\alpha = \{x \in X, \mu_A(x) \geq \alpha\}$$

where the set  $A_\alpha$  contains element with membership degrees greater than  $\alpha$  in [0, 1]

Definition 7 A fuzzy number is a fuzzy quantity satisfying following conditions

1.  $\mu_A(x) = 1$  for exactly one  $x$
2.  $\{x: \mu_A(x) > 0\}$
3. The  $\alpha$ -cuts of A is closed intervals.

Definition 8 Fuzzy number M is a fuzzy set defined on the set of real numbers R characterized by means of a membership function by  $\mu_M(x):R \rightarrow [0,1]$ . Its open form is given as follows:

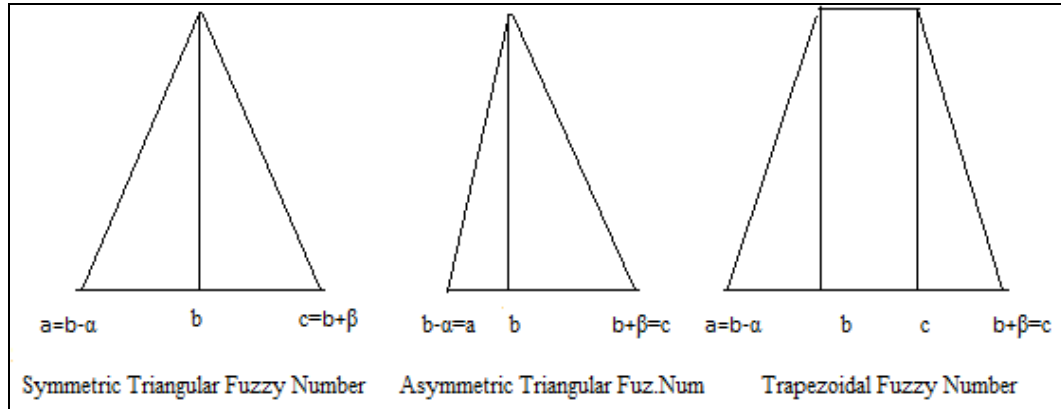
$$\mu_M(x) = \begin{cases} 0 & \text{for } x \leq a \\ f(x) & \text{for } a \leq x \leq c \\ 1 & \text{for } c \leq x \leq d \\ g(x) & \text{for } d \leq x \leq e \\ 0 & \text{for } x \geq b \end{cases}$$

Definition 9 Fuzzy number A is called LR (left and right) type fuzzy number if its membership function is defined by

$$\mu_A = \begin{cases} 1 & \text{for } x \in [\underline{a}, \bar{a}] \\ L\left(\frac{\underline{a}-x}{\alpha}\right) & \text{for } x \leq \underline{a} \\ R\left(\frac{x-\bar{a}}{\beta}\right) & \text{for } x \geq \bar{a} \end{cases}$$

Where L and R are continuous non-increasing functions on  $[0, \infty)$  and the parameters of  $\alpha$  and  $\beta$  are spread values which are positive numbers. Generally, L and R are called the shape functions. Fuzzy number A can be denoted easily by  $A = (a, \alpha, \beta)$  in the parametric form where “a” is center value, “ $\alpha$ ” is the left spread and “ $\beta$ ” is the right spread value respectively.

Various types of fuzzy numbers are available in the literature depending upon the nature of problems encountered in several disciplines. However, three of them called symmetric triangular fuzzy numbers, asymmetric triangular fuzzy numbers and trapezoidal fuzzy number are the ones that are mostly used in various disciplines. The shapes of both symmetric and asymmetric triangular fuzzy numbers and trapezoidal fuzzy number are depicted below.



**Figure 2. Special Fuzzy Numbers**

A question arises about what they mean and how they are used in applications especially in FRBS. When a linguistic term is at hand, a membership function is necessary. Fuzzy numbers are special membership functions satisfying some useful properties suited for applications in several disciplines. They can be written either in functional or parametric form. When they are written in parametric form, it is denoted by STF = (b, α, β) where “b” is the center value, “α” is the left spread value, “β” is the right spread value. STF stands for symmetric triangular fuzzy number. Knowing that α and β are spread values, it is easy to determine the end points of STF by doing calculations, b-α, for left side and, b+β, for right side respectively. Also, parametric form can be translated into functional form defined by

$$STF = \begin{cases} \left(\frac{x-a}{\alpha}\right), & a < x < b \\ 1, & x = b \\ \left(\frac{c-x}{\beta}\right), & b < x < c \end{cases} \tag{2}$$

In FRBS applications using Mat Lab 7.9 software, parametric form is only the one that can be used due to feature of the software.

Up to this point, a concise coverage of fuzzy set theory is given. All these concepts previously given will be the building blocks of Fuzzy Rule Based Systems.

Before getting started with Fuzzy Logic, we need to mention the background of the fundamental notion of it that is called Binary Logic. Binary logic is a special case of fuzzy logic by categorizing elements into two different situations coded as either 0 or 1 where 0 represents not being the member of the set and 1 represents being the member of the set. Therefore, it does not take into account the elements having partial membership degrees. Its corresponding mathematical function is called the characteristic function or indicator function, which is also the special case of membership function, defined as follows:



$$\chi_A(x) = \begin{cases} 1, & \text{if } x \in A \\ 0, & \text{if } x \notin A \end{cases} \quad (3)$$

On the other hand, fuzzy logic, which is a multi-valued logic, is the extension of binary logic. Therefore, it is suitable to represent elements having partial membership degrees. Its corresponding function is called membership function whose definition is previously given.

In statistics, fuzzy logic benefiting from fuzzy sets is used to use either fuzzy data or fuzzified data in the representation and manipulation of imprecise information for the purpose of statistical inference in order to construct model between independent and dependent variables. Fuzzy Set Theory and Fuzzy Logic constituting of Fuzzy Rule Based Systems, which is a modeling method employed in wide range of disciplines ranging from engineering to social sciences field. Fuzzy Rule Based Systems contains a list of rules extracted from data representing relations between a set of independent variables and dependent variable written in the form of IF-THEN rules consisting of IF part called antecedent condition where input variables taking values and THEN part called consequent condition where output variable taking its value.

When Fuzzy Rule Based System is concern, the variables both in input and output are either linguistic variables or fuzzified variables of crisp ones taking real numbers are employed. The aim of constructing FRBS is to develop a model expressing relationship between independent variables and dependent variable. We herein are not able to give a covering literature review. However, we can mention some recent literature in various disciplines emphasizing specially in social science and health and medical literature. Some recent research articles from engineering can be found in (Ishibuchi et al. 1998; Huang et al. 2009; Smoczek, Szpytko 2014). Manuscripts adapting FRBS in the field of social science can be found in (Basaran et al. 2011; Ustundag et al. 2010; Coskun et al. 2014). Medical studies adapting this method evaluated human health and urban environment sanitation relationship (Canavesa et al. 2013), to determine cancer risk by applying fuzzy if-then rules for input concentrations of radium isotopes in produced water (Shakhawat et al. 2006), for medical diagnosis of cardiovascular diseases (Sanz et al. 2014) and to research doctor-patient health communication (Demir et al. 2016). It can be noticed that articles applying FRBS to health area or medical research are very few; on the other hand, recent years are witnessing the growing attention to the subject.

One of the advantage of FRBS is that there is no prior knowledge available about the relationship structure between input and output but qualitative knowledge is available in the form of verbal statements. FRBS is a statistical/a mathematical model aiming at constructing the description of the system based on information by translating linguistic rules into mathematical expressions using fuzzy sets and fuzzy logic and defuzzifying the combined fuzzy output.

Definition 10 Consider a system where input data vector is denoted by  $x = (x_1, x_2, \dots, x_n) \in R^n$ , which is n dimensional vector, will generate  $y \in R$ . Suppose that the mathematical structure generally expressed in the form of  $y = f(x)$  is unknown. The behavior of the output with respect to input described as a collection of linguistic rules can be written as follows:

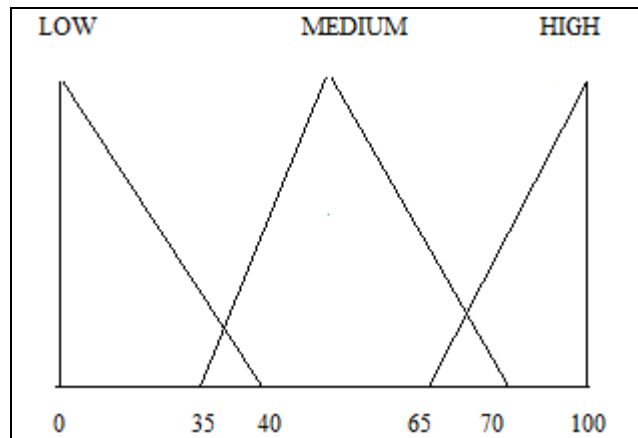
$$R_i: \text{IF } x_1 \text{ is } A_{1i}, x_2 \text{ is } A_{2i}, \dots, x_n \text{ is } A_{ni} \text{ THEN } y \text{ is } B_i, i=1,2,\dots,k$$

where  $A_i$ 's and  $B_i$ 's are fuzzy sets. Then the mathematical model is called FRBS.

The steps of implementation of FRBS, which is also called Mamdani type, can be summarized as follows:

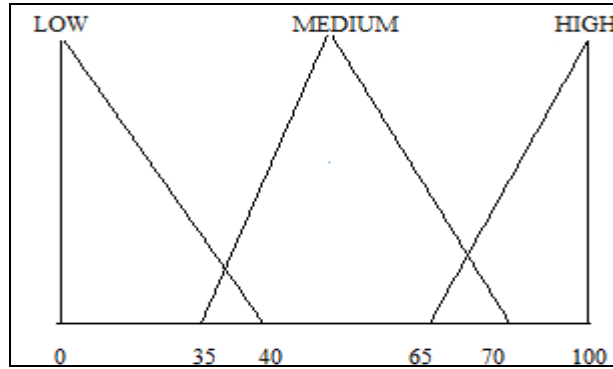
1. Fuzzification step: Transforming numerical values into linguistic values (If necessary).
2. Constructing IF-THEN rules using available data or past experiences.
3. Running model in order to reach inferences.
4. Defuzzifying: Transforming linguistic values into numerical ones (If necessary)

In order to illustrate what have been done, we exemplify each step using our original data. In FRBS, two types of data can be used. The first of which is original verbal data, for example, Linguistic Problem (LP) that is actually linguistic variable whose values are recorded with verbal statements such as “LOW”, “MEDIUM”, and “HIGH”. Since they are linguistic variables, fuzzy set theory is used to assign membership functions in order to represent them mathematically. The membership functions assigned to linguistic values are chosen as symmetric triangular functions which are depicted in Figure 3.



**Figure 3. Linguistic Values for Language Problem**

The intersection areas between them, for example, “LOW” and “MEDIUM” shows that the gradual transaction, which makes model more flexible, from one fuzzy set to another fuzzy set is taken into account. If one is comfortable with the language spoken, then he is assumed to have no language problem implying that he has “LOW” language problem. The scale of 0-100 is an ordinary measurement used in any kind of evaluation. If it is made in other scales different than 0-100, it makes no burden on modeling. Similar construction can be done for both other independent variables and dependent variable called Health Care Service Satisfaction (HSS) whose values are “LOW”, “MEDIUM” and “HIGH” using the scale between 0-100 depicted in Figure 4 below. The construction of other input variables follows the same procedure.



**Figure 4. Linguistic Values for Healthcare Service Satisfaction Variable**

Table 1 describes linguistic values and their membership functions given in terms of symmetric triangular fuzzy numbers. Those fuzzy numbers can be assigned in two different ways. While the first way of assigning them can be based upon expert knowledge, the second way is based upon collecting data from participants and then average values can be computed and used in the end.

**Table 1. Fuzzy linguistic variables and numerical values of their membership functions**

Input Variables				Output Variable
DPC	LP	MS	CD	HSS
L=(0,0,40)	L=(0,0,40)	L=(0,0,40)	L=(0,0,40)	L=(0,0,40)
M=(35,55,70)	M=(35,55,70)	M=(35,55,70)	M=(35,55,70)	M=(35,55,70)
H=(65,100,100)	H=(65,100,100)	H=(65,100,100)	H=(65,100,100)	H=(65,100,100)

**Legend:** DPC = Doctor-Patient Communication, LP = Language Problem, MS = Minority Status, CD = Cultural Differences, HSS = Healthcare Service Satisfaction, L = LOW, M = MEDIUM, H = HIGH

Table 1 denotes the membership functions written in the form of symmetric triangular fuzzy numbers that will be used in FRBS. It is noted that each value of linguistic variable should correspond to a membership function which is written in the parametric form so that FRBS employs them. Instead of writing mathematical function, the parametric form consisting of numerical values, for example, “MEDIUM” = (35, 55, 70) is written since MatLab accepts fuzzy numbers written in parametric form. The membership function for “MEDIUM” can also be defined in functional form by

$$\mu_{\text{MEDIUM}} = \begin{cases} \left(\frac{x-35}{20}\right), & 35 \leq x < 55 \\ 1, & x = 55 \\ \left(\frac{70-x}{15}\right), & 55 < x \leq 70 \end{cases} \quad (4)$$

After manipulating and organizing variables based on fuzzy set theory and fuzzy logic, data is ready to be expressed in the form of rules. for example, one of the responses is recorded as follows:

Doctor-Patient Communication (DPC) = “LOW”, Language Problem (LP) = “MEDIUM”, Minority Status (MS) = “LOW”, Cultural Differences (CD) = “MEDIUM” and dependent variable, namely, Health Care Service Satisfaction (HSS) = “MEDIUM”

We transform those linguistic values into the datum which is expressed in terms of Fuzzy IF-THEN statement that eventually becomes rule in FRBS as follows:

***IF DPC is LOW and LP is MEDIUM and MS is LOW and CD is MEDIUM  
THEN HSS is MEDIUM***

Actually, MatLab does not accept the rule given above as it is. It needs to be written in the form of membership functions as follows:

***IF DPC is (0,0,40) and LP is (35,55,70) and MS is (0,0,40) and CD is (35,55,70)  
THEN HSS is (35,55,70)***

Then the rule given above is an actual rule that will be crunched by FRBS. After writing all rules in MatLab, FRBS is run. Then for specific values of input linguistic variables chosen by researcher, the output (HSS) can be observed. The last step of FRBS is called defuzzification procedure that maps membership function into crisp (real number) if necessary. The exemplified rule given above produces crisp value of 60 after defuzzification procedure is run. The usage of crisp values in science field such as engineering and mathematics can be more informative due to need to understand the system in terms of numerical values. Also, it is possible to use linguistic values as an output.

Some other technical manipulations regarding the modeling procedure is explained using our problem. Original verbal data are collected using 5 point likert-scale consisting of “Very Poor”, “Poor”, “Neutral”, “Good”, and “Very Good”. Those answers are modified by augmenting “Very Poor” and “Poor” as “Low”, “Neutral” as “Medium” and “Good” and “Very Good” as High. By doing so, we have two merits. The first one is to decrease the number of rules since it is the case that each variable has 5 different linguistic values then the number of rules theoretically would be  $5^5=3125$  (having 5 linguistic variables and each linguistic variable having 5 values) which would be much greater than the number of participants. The second one is that “very poor” and “poor” can be thought of reflecting similar opinions. Therefore, augmenting them seems to be no problem at all. After regrouping, the system has to deal with  $3^5=243$  rules. However, some of them are redundant or contradictory rules that have to be removed from the total list. Since this method is a data-driven method each response provided by respondent in data set is considered as a rule. The total number of participants is 387. After checking them whether there are same rules, namely, repetitions among them, the number of rules decreases to 231 separate rules. Due to repetitions among rules, the weights are assigned to them depending on how many times they are repeated. Rules are run using Mat Lab 7.9.

## **IV. RESULTS**

### **4.1. Descriptive Statistics**

The results of descriptive statistics suggest that respondents are mostly women, at the working age, mainly from Germany, Balkans and Turkey, with high school graduation. Migrants inhabiting Vienna are not new comers, but minorities.

**Table 2. Descriptive statistics**

		<b>Percentages</b>
<b>Gender</b>	<b>Female</b>	59.7
	<b>Male</b>	40.3
<b>Age (Years)</b>	<b>18-25</b>	19.1
	<b>26-35</b>	27.9
	<b>36-45</b>	23.8
	<b>46-55</b>	18.9
	<b>56+</b>	10.3
<b>Time In Vienna (Years)</b>	<b>3-</b>	5.9
	<b>4-6</b>	10.1
	<b>7-10</b>	12.9
	<b>11-15</b>	12.7
	<b>16+</b>	58.1
	<b>Missing</b>	0.3
<b>Nationality</b>	<b>German</b>	15.8
	<b>Bosnia-Herzegovina</b>	13.2
	<b>Croatian</b>	3.4
	<b>Macedonian</b>	3.6
	<b>Serbian</b>	37.2
	<b>Turkish</b>	26.8
<b>Education Levels</b>	<b>Literate</b>	0.5
	<b>Primary Graduates</b>	15.2
	<b>Second Level Graduates</b>	22
	<b>High School</b>	42.6
	<b>Vocational High School</b>	1.8
	<b>Graduate and High Graduate</b>	12.7
	<b>Missing</b>	5.2

#### 4.2 Exploratory Factor Analysis

Factor analysis with varimax rotation using principle component analysis method is conducted to research the factor structure. Factor analysis results show a 7 factor solution that explain %65 of the variance extracted. Rotated factor solution reveals that Language Problem 1 and Language Problem 2 can be combined as Language problem since both consist of similar items. The similar situation is also seen for Cultural Differences 1 and Cultural Differences 2. Therefore, after aggregation of those similar components for Language factor and Cultural Differences factors, five factors are reached. Table 2 denotes the 7 factor solution results with factor loadings.

**Table 3. Exploratory Factor Analysis**

	DPC	MS	LP1	HSS	LP2	CD1	CD2
(DPC1)	0.723						
(DPC2)	0.688						
(DPC3)	0.676						
(DPC4)	0.672						
(DPC5)	0.664						
(DPC6)	0.615						
(DPC7)	0.540						
(MS1)		0.820					
(MS2)		0.720					
(MS3)		0.629					
(MS4)		0.563					
(LP1)			0.883				
(LP2)			0.861				
(LP3)			0.720				
(LP4)			0.618				
(HSS1)				0.617			
(HSS2)				0.559			
(HSS3)				0.555			
(HSS4)				0.554			
(HSS5)				0.516			
(LP5)					0.826		
(LP6)					0.698		
(LP7)					0.668		
(CD1)						0.784	
(CD2)						0.701	
(CD3)							0.845
(CD4)							0.733

**Legend:** DCP = Doctor-Patient Communication, MS = Minority Status, LP1 = Language Problem1, HSS = Health Care Service Satisfaction, LP2 = Language Problem2, CD1= Cultural Differences1, CD2 = Cultural Differences2.

## V. FINDINGS

Four independent variables, namely, Doctor-Patient Communication (DPC), Language Problem (LP), Minority Status (MS), Cultural Differences (CD) and dependent variable, namely, Health Care Service Satisfaction (HSS) are variables used in Fuzzy Rule Based Systems (FRBS) in order to investigate the relationship between independent variables and dependent variable.

Before discussing in detail what has been found, we can simply tell that when all independent variables are fixed at average level which means that “MEDUIM” = (35,55,70) is chosen, Health Care Service Satisfaction (HSS) takes the average value, which means that “MEDUIM” = (35,55,70) is observed and after defuzzification, the numerical value is 57 which can be interpreted that the overall perceived satisfaction level by patients is average showing no bias at all. When defuzzification is realized, the centroid of area is used.

Also, the contribution of each independent or of their interaction effect on dependent variable is observed. When the effect of each independent variable on Health Care Service Satisfaction (HSS) is investigated, either increase or decrease of each variable does not

directly affect HSS except the variable called Cultural Differences (CD). Therefore, the only significant variable explaining HSS is CD. When CD tends to increase, HSS increases or vice versa. On the other hand, other variables play roles in either increase or decrease of HSS when interaction of them is taken into account. When Cultural Differences (CD) is dealt by doctors at high level in the treatment, the interaction of other variables has positive effects on HSS. for example, if a patient is comfortable with the fluency of his German and with no concern of being minority, these lead to reach high levels of HSS. Nevertheless, opposite situation, that is poor level of German and being felt of minority, causes decrease in HSS. Similar situation can be seen with the variable called Doctor-Patient Communication (DPC). for example, When DPC is allowed to take part as an interaction term with other variables affecting the increase of HSS, the highest level of satisfaction by patients is observed. Therefore, “the best” and “the worst” cases can be defined as follows:

The worst case: IF DPC is average and MS is average and LP is average and CD is low, THEN HSS is low. When rule is translated into fuzzy numbers it written is as follows:

IF DPC is (35,55,70) and MS is (35,55,70) and LP is (35,55,70) and CD is (0,0,40)  
THEN HSS is (0, 0, 40)

After defuzzification, HSS=18.

The best case: IF DPC is high and MS is average and LP is low and CD is high, THEN HSS is high.

When rule is translated into fuzzy numbers it written is as follows:

IF DPC is (65, 100, 100) and MS is (35, 55, 70) and LP is (0, 0, 40) and CD is (65, 100,100) THEN HSS is (65, 100, 100).

After defuzzification, HSS=88.

As a result, the fundamental expectation in the evaluation of Health Care Service Satisfaction by minority patients is the respect to Cultural Difference (CD) shown by doctors. If it is met at the first glance, HSS tends to increase. If not, HSS is observed at low level. Other variables play key roles in the increment of HSS when minority status (MS) and language problem (LP) are being felt less. Then HSS tends to increase. The highest level of HSS is reached when Doctor-Patient Communication (DPC) tends to increase. On the other hand, when Minority Status (MS) and Language Problem (LP) are being felt heavily, HSS tends to decrease but it is not below average. Therefore, it can be said that their roles become significant with Cultural Differences being good taken care of. When Cultural Differences are taken care of by doctors in a way patients feel satisfied, interaction of other variables has directly positive effects on Health Care Service Satisfaction.

## **VI. DISCUSSION**

In the literature, the problems the minorities or different cultural groups encounter are the difficulty of establishing an effective and satisfying doctor-patient relationship, which has direct impact on health care service satisfaction. Major differences in doctor-patient communication are reported because of patients' ethnic backgrounds. The mixture of less affective doctors and less verbally expressed and recessive patients on decision of their treatment is the key attitudes causing complaints (Schouten, Meeuwesen 2006). Also, that the need to better serves minorities is a result of increasingly diverse societies expanding around the globe is called culturally sensitive health care (Shpilko 2006). In order to have

good communication with minority patients, respect and people-focused attitude are reported as a vital step which reduces patients' misunderstanding and uncertainty, improving management decisions and resulting in a more satisfied patient at the end (Booker 2005).

Also, the strength of this study is to depend upon findings revealing some relations in the evaluation of Health Care Service Satisfaction (HSS). Among minorities, Cultural Difference (CD) is the only variable that has direct impact on HSS. If it is believed to be met at the initiation of service by patient, other variables then take positive roles in better evaluation of HSS. Especially, Doctor-Patient Communication (DPC) is attributed as another important variable affecting HSS. DPC is seen more important than other variables. Therefore, what we find out can be translated into practice as follows: sequential approach should be taken towards minorities when HSS is concern. In the first phase, Cultural Differences should be good taken care of and respected by doctors before initiating medical treatment. In the second phase, Doctor-Patient Communication (DPC) is better established by avoiding issues already mentioned in the literature since it is key factor playing effective role on obtaining high level of Health Care Service Satisfaction.

The objective of this study is two-fold. One of which is to crunch data differently than do traditional approaches. By doing so, collected originally verbal data without loss information using fuzzy set theory and fuzzy logic capable of representing imprecision inherited in natural languages is directly used. The second one is to construct mathematical model called FRBS based on fuzzy set and fuzzy logic between input variables and output variables. By doing so, which inputs variables and/or interaction of input variables have effects on output variable can be observed.

Fuzzy set theory can be operationalized in healthcare service administration activities (Goh et al. 2018; Abdi 2018), to profile age, sex, medication records and disease to predict the possibility of a patient or some disease (Li et al. 2017; Sudha, Grijamma 2017), as a tool for the risk prioritization in surgical flow disruption effects. The occupational safety and health risks (Bas 2018), and for patient satisfaction (Wan, Alagar 2017). The medical and healthcare data contains a lot of rich information that needs to be analyzed. Fuzzy set theory is a part of big data analysis methods that offers opportunities for healthcare administration.

The limitation of this study is not to measure the effects of different minorities on Health Service Satisfaction due to not having available data.

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