Fuzzy Logic and Fuzzy Clustering for Medical Service Value Model

Wiyada Kumam and Adisak Pongpullponsak

***Abstract*—This research is to expand an estimation model for medical service value of informal workers for the social security system. In this study, the data of workers in year 2010 provided by the Social Security Office in Thailand was analyzed and used to create for non-surgical medical service value model.**

The data obtained from the fuzzy clustering analysis is used to establish a membership function in fuzzy logic. Subsequently, the result from this model, which is compensation for medical expenses will be used to estimate the monetary value of medical services for the informal workers when receive the treatment without surgery.

***Index Terms*—fuzzy clustering, informal workers, fuzzy logic, fuzzy equivalent relation, medical service value**

I. Introduction

THE Social Security Office of Thailand has attempted to extend the social security program to informal workers covering 4 benefits as follows: (i) costs of medical treatment, (ii) compensation for unemployment, (iii) funeral expenses and (iv) financial aid. The study has started by a study of [14] who defined target groups that should be included in the program and has attempted to establish a benefit system on medical services to informal workers. Based on treatment of patients, the expenses of medical services can be divided into 3 groups composing of group I where patients are admitted to a hospital for treatment without surgery, group II where patients are admitted to a hospital for surgical treatment and group III where patients receive treatment but are not admitted to a hospital.

For this research, the study is focused on patients who are admitted to a hospital for treatment without surgery and for the future work, the medical services values for the other two groups will be studied. In 1995, Baker and Krueger [1] determined a model for estimating medical costs and health compensation for insured persons under the social security system. In 2009, Jihong and Minglai [7] studied a theoretical investigation of the reformed public health insurance in urban China.

In 2011, Galbraith and Stone [5] introduced the abuse of regression in the National Health Service allocation formulae which is in response to the Department of Healths 2007 resource allocation research paper. Nawata et al. [11] and [12] studied the discrete-type proportional hazard model for estimating duration of hospital stay for cataract patients. From their reports, it is found that duration of hospital stay should be taken into account for medical service value model.

In estimation of medical service costs, it is found that if the ambiguous data has been used in the study, this might yield inaccurate results. To avoid such a problem, several researchers have adapted the principle of fuzzy for data analysis in their studies. In 2011, Ho [6] proposed a method for optimal evaluation of infectious medical waste disposal companies using the fuzzy analytic hierarchy process.

In 2011, Chen et al. [3] developed fuzzy clustering method in clustering the data of flood damage into dependent variables and independent variables. Bolotin [2] used fuzzification in linear regression models with indicator variables in medical decision making. Stefan [15] proposed tree types of fuzzy predictions of the observed variable in the classical regression model where unknown parameters and observations are crisp. Peduzzi et al. [13] defined a simulation study of the number of events per variable in logistic regression analysis using fuzzy clustering method for data allocation.

Recently, Laura et al. [10] studied logistic regression method to analyze the volume and nature of emergency medical calls during severe weather events.

The aim of this study is to develop a non-surgical medical service value estimation model of informal workers for the social security in Thailand by using the fuzzy clustering method and fuzzy logic.

II. Methods

A. The medical service value model

The data used in the study, is obtained from the surveys of informal workers of the social security, Thailand in 2010, included sex, age, weight, height, education, occupation, number of family members, income, number of medical visiting, length of hospital stay, costs of medical care.

Estimation of non-surgical medical expenses of patients can be done from analysis of length of illness and hospital stay, which is discrete random variable, where it equates to $1, 2, 3$ $etc.$ Nawata et al. in [11] and [12] analyzed the length of stay in hospital, which is depending on the severity of the case, using the discrete-type proportional hazard model. Thus, let the leaving rate, designated as $h_i(t)$, be a conditional probability that the i^{th} patient staying in a hospital on the t^{th} day will leave the hospital on that day.

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Therefore, the probability of patients i who can leave hospital on the t^{th} day is a function of $h_i(t)$ given by the following formula:

$$p_i(t) = \begin{cases} h_i(t), & t = 1 \\ [\prod_{s=1}^{t-1} \{1 - h_i(s)\}]h_i(t), & t \geq 2,\ i = 1, 2, ..., n, \end{cases} \quad (1)$$

where n is number of patients, s is number of days staying in the hospital an $s = 1, 2, , t-1$. Let v_i is random variable of medical expenses of patients i^{th}. From the continuous proportional hazard models by [11] and [12], we obtain an equation of risk incidence for various characteristics of patients as below:

$$h_i(t) = d_t exp(v_i^{'}\beta); t = 1, 2, 3, \ldots, T, \quad (2)$$

where d_t is the rate of patient staying in a hospital on day t^{th}, and β is regression coefficients of patient condition.

In 2000, [4], studied health insurance and pension plans to investigate the relationship between employee compensation and small business owner income by using regression analysis. From the equation (2) of [14], it reports that the estimation of $v_i^{'}\beta$ using regression method and expected value of non-surgical medical service of patients when they are not admitted to a hospital for treatment can be expressed by

$$E(C_{IN}(t)) = \int_0^t \nu_i h_i(t) d\nu_i = d_t \int_0^t \nu_i \exp(v_i'\beta) d\nu_i, \quad (3)$$

where $E(C_{IN}(t))$ is expected value of medical service value of patients are admitted to a hospital on t^{th} day for treatment without surgery.

B. Fuzzy cluster analysis

Let $X = \{x_{11}, x_{12}, ..., x_{nm}\}$ be the set of informal worker patients, where m is the number of the samples and n is patient characteristics. The fuzzy clustering analysis which is based on fuzzy equivalent relation, includes 4 steps (see [3] and [16]) as follows:

Step 1**:** estimation of the default value is by using the standardization;

Step 2**:** calculation the coefficient of the fuzzy similar matrix;

Step 3**:** the fuzzy equivalent matrix have 3 characteristics, $reflexivity, symmetry\ and\ transitivity$.
In case that the fuzzy similar matrix R does not satisfy transitivity, the fuzzy equivalent matrix on the basis of R will be generated by $R \to R^2 \to R^4 \to R^8 ...$ to $R^{2k} = R^k \circ R^k$, at this time, R^k is a fuzzy equivalent matrix; and

Step 4**:** clustering the data can be done by considering the values of $\lambda (0 \leq \lambda \leq 1)$.

C. The fuzzy logic

The fuzzy system of independent variable was determined by triangular membership function and trapezoidal membership function could be defined as follows:

$$\text{trimf}\,(x : a, b, c) = \begin{cases} 0 & ; x < a \\ (x-a)/(b-a) & ; a \leq x < b \\ (c-x)/(c-b) & ; b \leq x < c \\ 0 & ; x > c \end{cases} \quad (4)$$

and

$$\text{trapmf}\,(x : a, b, c, d) = \begin{cases} 0 & ; x < a \\ (x-a)/(b-a) & ; a \leq x < b \\ 1 & ; b \leq x < c \\ (c-x)/(c-b) & ; c \leq x < d \\ 0 & ; x > d. \end{cases} \quad (5)$$

III. Results

From using the fuzzy clustering method, the data can be divided into three groups (see also [8] and [9]). Each data group is then used in establishing a membership function of independent variable and the next step is to establish the medical services value model in equation (3), the data used in establishing the model obtained from a questionnaire to survey the medical care of informal workers.

By using Matlab, the medical services value model can be created based on fuzzy rule, if informal workers who are age and sex and income and number of medical examination and number of family members then medical costs 1 day and 2 day and 3 day, as shown in Figure 1 (below).

From the results, the medical services value model for estimation of hospital medical expenses of informal workers in Thailand for the case that they are admitted to a hospital for treatment without surgery can be established.

The model was then used to predict for the medical expenses as following. For informal workers who are 35 years at age and who are female and have income about $340,000$ bath and number of medical examination equal to 3 time and number of family members equal to 3 person then medical costs 1 day and 2 day and 3 day, the estimated medical services value will be $1,100$ bath, $3,340$ bath and $7,700$ bath, respectively, as shown in Figure 2.

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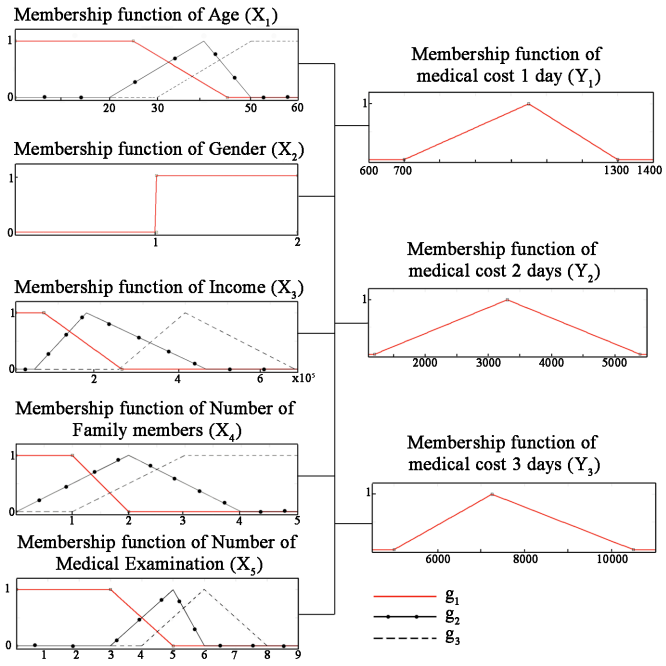

Fig. 1. The Fuzzy rule of this study

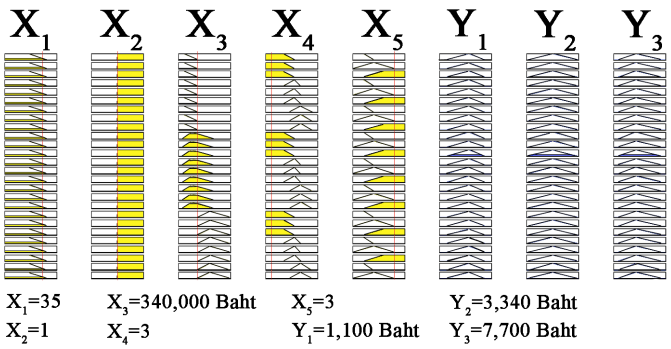

Fig. 2. Calculation of medical services value by Centroid method

IV. Conclusion

In this study we develop the medical service value model for estimation of hospital medical expenses of informal workers in Thailand for the case that they are admitted to a hospital for treatment without surgery. Using the fuzzy clustering method which is based on fuzzy equivalent relation, the data can be divided into three groups in which each data group is used in establishing a membership function in fuzzy logic. The result obtained from fuzzy logic is the estimated medical service value of informal workers in case of treatment without surgery. For the future work, the overview of the medical services value will be considered for the most suitable medical service value model.

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