Employee Likelihood of Purchasing Health Insurance using Fuzzy Inference System

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Abstract

Many believe that employees' health and economic factors plays an important role in their likelihood to purchase health insurance. However decision to purchase health insurance is not trivial matters as many risk factors that influence decision. This paper presents a decision model using fuzzy inference system to identify the likelihoods of purchasing health insurance based on the selected risk factors. To build the likelihoods, data from one hundred and twenty eight employees at five organizations under the purview of Kota Star Municipality Malaysia were collected to provide input data. Three risk factors were considered as the input of the system including age, salary and risk of having illness. The likelihoods of purchasing health insurance was the output of the system and defined in three linguistic terms of 'Low', 'Medium' and 'High'. Input and output data were governed by the Mamdani inference rules of the system to decide the best linguistic term. The linguistic terms that describe the likelihoods of purchasing health insurance were identified by the system based on the three risk factors. It is found that twenty seven employees were likely to purchase health insurance at 'Low' level and fifty six employees show their likelihoods at 'High' level. The usage of fuzzy inference system would offer possible justifications to set a new approach in identifying prospective health insurance purchasers.

Keywords: *Health Insurance, Fuzzy rule, Risk factor, Fuzzy logic, Likelihoods*

1. Introduction

The area of insurance was introduced since three decades ago and now very often becomes part of individual's life. Insurance plays very important industry as it captures the future unpredictable events. It is defined as a form of risk management primarily used to hedge against the risk of contingent loss. There are many type of insurance and one of the most common insurances in health concern societies is health insurance. The term health insurance is generally used to describe a form of insurance that pays for medical expenses. In a modern era today, peoples are more concern about their health care and protection of their wealth. This situation makes health insurance has become one of a must buy insurance coverage. It was reported in Australia that between 1997 and 2001, the health insurance market underwent a rapid transformation as these reforms have increased the insurance coverage amongst order people [1]. Healthcare insurance enables access to care by protecting individuals and families against the high and often unexpected costs of medical care. The 2002 Population Survey reports that nearly eighty three percent of the under-age-sixty-five population in the United States had health insurance. More than three-quarters of these people had coverage through an employer, fewer than 10 percent purchased coverage on their own, and the remainder had coverage through a government program [2].

As to meet health care of the present markets, insurance industries have identified several key factors that may affect insurance prices. A recent study by PricewaterhouseCoopers [3] examining the drivers of rising health care costs in the United States. The report pointed to increased utilization of health care costs was created by increased consumer demand, new treatments, and more intensive diagnostic testing, as the most significant. These significant demands are definitely relate to factors that influence people in purchasing health insurance. The risk factors of age, lifestyle, health conditions and purchasing power, among others, are all affecting to the demand for health insurance. Risk of illness and the attendant cost of care lead to the demand for health insurance. Besides consumers' health and wealth conditions, claim provisions and attractive benefits to claimers are also important to motivate people in purchasing health insurance. However, the affects of

these factors toward likelihoods of purchasing insurance are still not conclusive. This view is supported by McLaughlin, et al. [4] who writes that although obtaining health insurance is voluntary in the U.S., surprisingly little is known about the factors that determine individual to obtain health insurance.

Many approaches have been proposed to understand performance of purchasing health insurance. In Taiwan, for example, performance of health insurance industry, was investigated by Liu and Chen [5] using a survey and expenditure data. They investigate the factors influencing the probability and amount of private health insurance purchased using a two-part statistical model of logistic and ordinary least squares regressions. However, unpredictable future and uncertain behaviors of insurance do not make it advisable to forever rely on statistical approaches. Alternatively, approaches using fuzzy sets theory have been flourished in insurance analysis as an alternative or complement to statistical approaches. Ostaszewski [6] was among the first to suggest the use of the *c*-means algorithm for classification in an insurance context. Cummins and Derrig [7] used fuzzy approach to forecasts of automobile bodily injury liability pure premiums. Besides forecasting for premium using fuzzy multiple criteria, fuzzy sets have been used in classifications. Horgby [8] describes how to classify risks by using a fuzzy inference methodology. By defining risk factors as fuzzy sets, it is shown that an insurer can utilize multiple prognostic factors that are imprecise and vague. Apart from forecasting and classification, fuzzy set theory has also been used in evaluation for purchasing insurance. Chin et al, [9] proposed an evaluation model for purchasing life insurance and annuity insurance using a combination of pair-wise comparisons of analytical hierarchy process and fuzzy logic. Four factors were considered as the inputs of the proposed model including age, annual income, educational level and risk preference. The significant role of fuzzy logic in insurance was stressed by Shapiro [10]. He asserts that insurance industry has numerous areas with potential applications for fuzzy logic. These include classification, underwriting, projected liabilities, fuzzy future and present values, pricing, asset allocations and cash flows, and investment. Given these potentials and the impetus on fuzzy logic during the last decade, it is not surprising that a number of fuzzy logic studies have focused on insurance applications. Fuzzy logic is seemed as a tool in insurance pricing decisions that consistently consider vague data. However, far too little attention has been paid to classify the impact of risk factors to likelihood of health insurance purchasing. As an initiative to empower the decision tool using fuzzy logic, this paper proposes another study of fuzzy logic to health insurance purchasing potential. The whole package operations of fuzzy logic have been translated magnificently into fuzzy inference system (FIS). FIS based on fuzzy rules has been applied to numerous engineering applications such as control, signal processing, and pattern classification problems [11][12].

The notion of fuzzy sets in forecasting, classifications and evaluations of insurance fraternity was further explored. The possibility of extending fuzzy inference to classify likelihoods of purchasing health insurance is always plausible. Likelihood of purchasing health insurance based on their risk factors is intended to investigate in this paper. Specifically, this paper aims to propose the likelihoods of purchasing health insurance in form of linguistic terms using FIS. This paper is organized as follows. As to make this paper self-contained, Section 2 describes a brief introduction of FIS. A case study of likelihoods of purchasing health insurance using FIS among selected employees is explained in Section 3. Finally this paper ends with conclusions in Section 4.

2. A Brief of Fuzzy Inference System

Fuzzy inference system is a popular methodology for implementing fuzzy logic. FIS is one of the most famous applications of fuzzy logic and fuzzy sets theory [13]. It is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. FIS is sometimes called fuzzy reasoning or approximate reasoning. It is used in a fuzzy rule to determine the rule outcome from the given rule input information. Fuzzy rules represent control strategy or modeling knowledge/experience. When specific information is assigned to input variables in the rule antecedent, fuzzy is needed to calculate the outcome for output variables in the rule consequence.

FIS are also known as fuzzy rule-based systems, fuzzy expert systems, fuzzy models, fuzzy associative memories, or fuzzy logic controllers when used as controllers. The main components of the system include fuzzification interface, inference engine and deffuzification. Basic structure of FIS that comprises three components and rules can be seen in Fig 1.

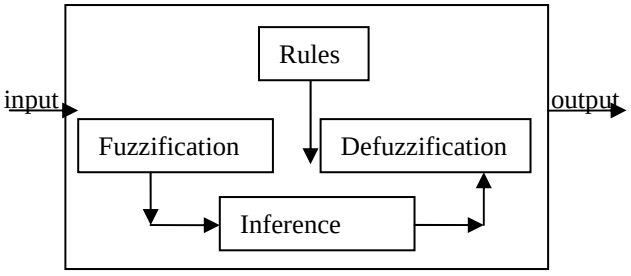

Fig 1 Basic structure of a fuzzy inference system

FIS can be envisioned as involving a knowledge base and a processing stage. The knowledge base provides membership functions and fuzzy rules needed for the process. In the processing stage, numerical crisp variables are the input of the system. These variables are passed through a fuzzification stage where they are transformed to linguistic variables, which become the fuzzy input for the inference engine. This fuzzy input is transformed by the rules of the inference engine to fuzzy output. These linguistic results are then changed by a defuzzification stage into numerical values that become the output of the system. Therefore creating decision using FIS may involves several steps. The steps in FIS are used to test a case study of likelihoods in purchasing health insurance. The steps specifically tailored to the objective of this paper are explained in Section 3.

3. A Case of Health Insurance Purchasing

The FIS is tested to one hundred and twenty eight employees who are working at government and public sectors in Kota Star Municipality of Peninsular Malaysia. Three important input variables that may influence the likelihoods of purchasing health insurance are identified. In this case study, the input variables are age, salary and risk of illness. The system uses Mamdani inference [1] which allows a system to take in a set of crisp input values and apply a set of fuzzy rules to those values, in order to derive a single, crisp, output value. The following steps are executed to obtain likelihoods in purchasing health insurance.

Step 1: Defining input and output

The factors of likelihoods of purchasing insurance are become the input of this Mamdani inference and the output of the system is likelihoods of purchasing health insurance. Fig 2 illustrates how the inputs related to the health insurance are being processed to create the output.

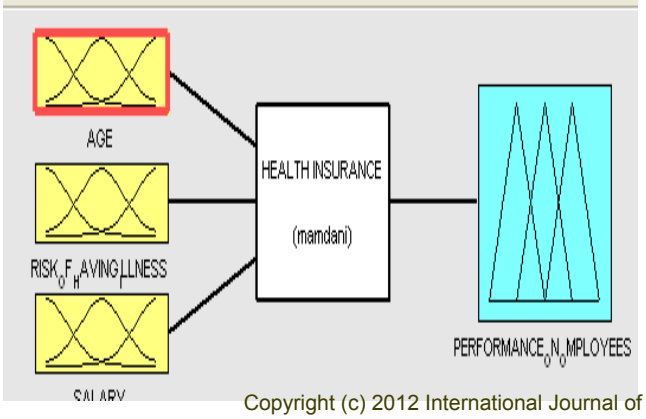

Fig 2 Input and output of the system

Likelihood of purchasing health insurance is labeled as 'performance on employees' in the system as to indicate the employees' capability in purchasing health insurance. Based on the defined system functional and operational characteristics, input crisp data from this experiment are needed to fuzzify.

Step 2: Defining Fuzzy Sets for System Variables

System variables need to fuzzify in order to obtain fuzzy membership. The system recognizes the input and output variables and defines its memberships. Memberships for risks of illness, for example are defined in three linguistic terms, 'High', 'Medium' and 'Low'.

Step 3: Defining Fuzzy Rules

The next step is defining the If-Then rules to describe system behavior. The rules are designed as to describe the importance of the factors on employees over the possibility of purchasing health insurance. At this step, data from employees are entered into the system. Based on the expert knowledge, this study expresses the problem in terms of logical rules.

For examples, if three respondents were considered, then the rules are given as follows.

Rule 1 (respondent 1) IF age is 25 years old AND the risk of having illness is low AND his salary is RM 2678.00 THEN his likelihoods to buy health insurance is medium.

Rule 1 (respondent 2) IF age is 47 years old AND the risk of having illness is high AND his salary is RM 3472.00 THEN his likelihoods to buy health insurance is high

Rule 1(respondent 3) IF age is 31 years old AND the risk of having illness is medium AND his salary is RM 720.00 THEN his likelihoods to buy health insurance is low

These fuzzy rules are executed for all respondents. Part of the fuzzy rules is shown in Fig 3.

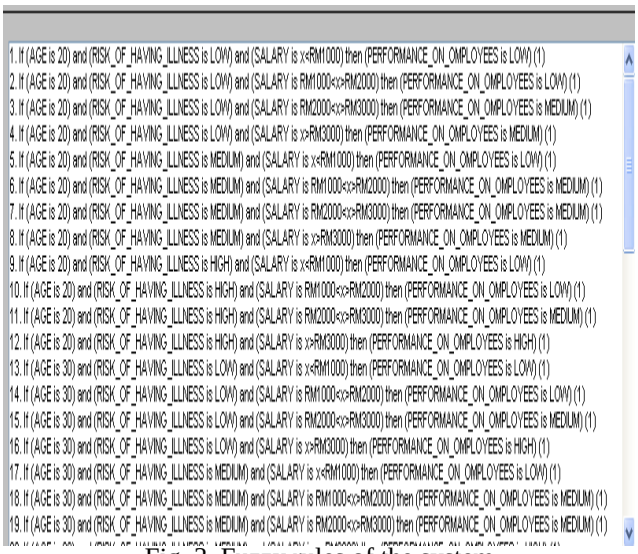

Fig. 3 Fuzzy rules of the system

The inference rules set the premise to create output. The output, then need to defuzzify in order to obtain crisp value.

Step 4: Defuzzification

Finally defuzification step is needed to convert all input data into three linguistic terms that can be used to observe the likelihoods of purchasing insurance. The defuzzification process transforms the fuzzy set into a crisp value that is meaningful to end-user. For example, if respondent's age is 43 years and his risk of having illness is medium and his monthly salary is RM 2800.00 then the defuzzification result shows the output is 52. Thus based on the defined output, the likelihood of the employee over the capability of purchasing health insurance is 'medium'. Part of the processes is shown in Fig 4

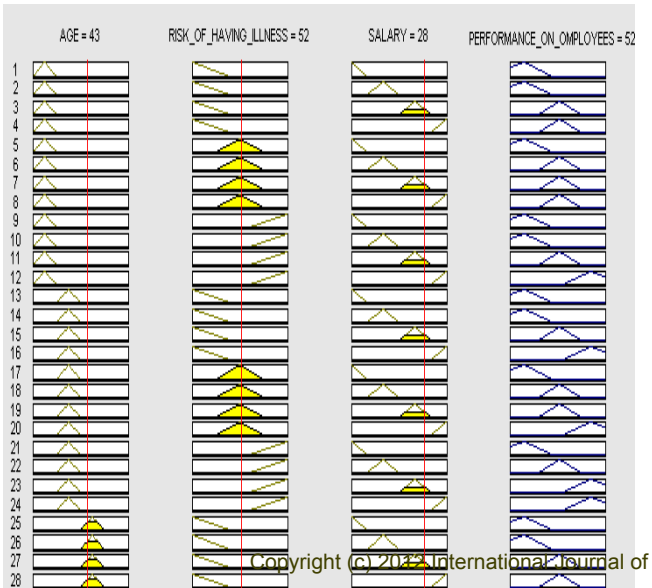

Fig 4 Defuzzification Process

Results for the rest of employees can be obtained with the similar fashion. The likelihoods of purchasing health insurance and the risk factors are partly shown in Table 1.

Table 1 Likelihoods and risk factors of purchasing health insurance

Employee	Age (year)	Risk of illness	Salary (RM)	Likelihoods
1	43	Medium	2800	Medium
2	56	Medium	3500	High
3	38	High	3060	High
4	22	Low	870	Low
5	28	Low	1210	Low
6	23	Low	1610	Medium
7	24	Low	1864	Medium
8	37	Low	1280	Low
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
128	28	Low	2265	Medium

The system ultimately decides the likelihood of purchasing health insurance in one out of three linguistic terms for each employee. The likelihoods of purchasing health insurance are either 'Low', 'Medium' or 'High' . The decisions obtained are based on the three input variables and one output variable governed by the fuzzy rules in FIS. Summarily the likelihoods of purchasing health insurance for one hundred and twenty eight employees are tabulated in Table 2.

Table 2 Number of employee and their likelihood

Likelihoods	Number of employee	Percentage
High	56	43.8
Medium	45	35.1
Low	27	21.1

The descriptive percentage analysis shows that the likelihood of 27 employees (21.1%) to purchase health insurance is 'Low' and the likelihood of 45 employees (35.1%) is 'Medium'. The likelihood of 56 employees (43.8%) is 'High'. Based on the three inputs, this study has shown that FIS successfully classified the likelihoods of employees into the three linguistic of 'High', 'Medium' and 'Low'. The results of this study indicate that it is very difficult to determine the risk factors that can predict the likelihood of purchasing health insurance.

4. Conclusions

An important element in determining the likelihoods of purchasing health insurance is a method which can take into account the multi factors. The method should establish a decision to reflect the contribution of each accounted factor. Furthermore the method should be practical, direct analysis and the most important is the results are easily understandable. In this paper, the fuzzy rules based method to classify the likelihoods of purchasing health insurance was utilized. The system uses fuzzy inferences that can encode the researchers' expertise to reach decision. Three risk factors that affect the potential of purchasing health insurance were considered including age, salary and risk of illness. The system recognized the likelihoods in one out of three linguistic terms intelligently adjusted by the system. The results reveal the effectiveness of the system in identifying the likelihoods of purchasing health insurance. The system can be used as a tool by insurance company in the process of indentifying prospective purchasers. Future research can be extended to rank the risk factors in accordance with employees' preferences using other intelligent methods such as analytic hierarchy process or any other non parametric tests.

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