Fuzzy Based Pricing Model for Old Age Insurance

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Abstract

There cannot be any doubts that insurance needs in old age are fundamentally different to those in the early and middle periods of life. In the early parts of life a primary goal is to protect against crises in life, for example disability, death, dreaded/chronic diseases and personal accident policies. Such potential crises do not apply in the same form in advanced years. While in middle age the focus is either on wealth accumulation or paying off the debts, for example mortgage on a home, personal loans, paying off premiums for retrials benefits and making periodic investments. These insurances have often already been redeemed by old age. At a later stage in life prominent risks are identified with severe illnesses, the need for nursing care, the loss of close relatives, accidents and injuries as well as the loss of self-sufficiency (financial security) in general. It is true that various type of insurance can be modified to cater to some of these risks but does not address the need of coverage against other risks, associated with old age.

This work presents a model which is designed using fuzzy mathematics and expert system. This model will provide indicative result on the old age insurance pricing process. The methodology is also supported with an example.

Keywords:
Inference rule Fuzzification, Insurance

1. Introduction to Problem and Significance

Various organizations across the world are concerned about demographic change in composition of various cultures, races across the world. These changes have been observed in entire world and are closely associated with a change in social structures, especially within the family. Until a decade before, it has been a tradition of generations, to take care of parents and grandparents and ensure their well being in last stages of their lives. But this pattern of care is no longer feasible against the backdrop of the evolving nuclear family. Figures show that, there is a steady growth in population, aged over 60 years, across the globe whether it is a developed countries or a developing nation. More and more elderly people are finding themselves compelled to arrange for their old age and protect against probable risk. This emerging trend has not yet been identified as a business opportunity by most of the insurance companies. People live long even after 60 years and are in need of risk cover associated with old age. Insurance companies provide some risk cover to the elderly by charging heavy premiums. As it is hard to predict longevity after 60, companies tend to minimize their own risk through maximum premium.
This work will discuss in brief attributes contributing to longevity and accounting them in calculating a risk which can be primary factor in calculating premiums to be charged to elderly.

This adjustment factor can be applied to the base amount to derive a reasonable premium.

2. Changing Lifestyles and Key Attributes

The changing social environment, socio economics and lifestyles have already discussed earlier, now we will try to map these changes with key attributes contributing this change.

2.1 Social Index

The social index is an indicator of the social well being of an individual. During early age these factor does exist as youth is more focus towards career growth, money, power and individuality. During later years people look towards stability, family, home, and relatives and friends, therefore few of these and their relation to longevity is highlighted here:

Single or Married: Companionship is a basic human need and you realizes its need as you grow old. Being single gives an individual acute sense of loneliness resulting in depression, ill health and finally short life. There are clear evidences that a married individual lives longer than a single.

Being at home: Being at one’s own home gives immense sense of security, belongingness and comfort as compared to staying in old age homes or relatives or at mercy of others. These factors get more critical if people are fit and healthy but due to some reason could not have their own place to reside. People with successful career, good health and own dream house live long as compared to people without it.

Kids, Relatives and Friends: These are the bonds which drive all people to work hard and be successful in life so that one day when they retire and enter old age they can spend quality time with all their loved ones. Had there been no relation to connect to, people would have found no motive in living long lives. Kids, Relatives and Friends give an individual a deep sense of value, pleasure and satisfaction, for which they worked all their youth. So being surrounded by your loved ones increases your life line.

2.2 Socio Economic Index (Education, Previous Occupation and Income)

Besides social index, there are other indexes also which can measure our well being. This Socio Economic Index can be very vital in determining my needs and associated risk during old age. We will discuss few key contributors to this index in details below and how they are linked to well being during old age.

- Education: The quality of education, both formal and professional is the key to successful careers. People who received formal education in good institutes get into great universities / academia and swiftly moved into high paying jobs where as all those who could not get into good education have less chances of getting into high paying careers and forced to live sub standard life. Good quality education gives people a broader outlook towards a life and to great extent ensures your well being

- Previous occupation: Nature of jobs cultivates a culture in each individual that commands his/her thought process all their lives. Hence nature of job, profile and environment will
determine where one's career will end and what will be capabilities at the time of retirement.

- Income: Financial appetite of an individual is a direct indicator of one's capabilities to afford luxuries in this world. High net worth individuals do not face the challenges of life which a common man faces in meeting his /her daily needs. People worn out in middle ages, they develop health problems due to malnutrition, bad hygiene and stressful life.

2.3 Self-Sufficiency Factor

- This factor describes the ability of an individual to perform his day to day activities independently (without any help). For analysis sake let's segregate activities into two categories viz. DAL (Daily Activity List) and DIAL (Daily Instrumental Activity List). These activities contribute in determining the factors in equation below.
- The daily instrumental activities list (DIALs) includes the following key functions:
  - Elderly can perform daily household work without help
  - Elderly can prepare daily meals without help
  - Elderly can dress and undress without help
- The daily activity list (DALs) includes the following key functions:
  - The elderly has ability to participate in social activities
  - The elderly has ability to use public transportation
  - The elderly has ability to prepare and eat food
  - The elderly has ability to move around one's home
  - The elderly has ability in dealing with financial matters
  - The elderly has ability to take care of laundry

2.4 Health Index

Health Index is the measurement of fitness of one’s body. People suffering from chronic or acute diseases have a short span of life and they suffer from mental stress and depression. Also people suffering from such diseases are dependent on others to a large extent for their well being.

3. Methodology

Our study is based on self-sufficiency analysis which varies with every individual and can actually help insurance companies in determining the profitable policy holder. The outcome is a win-win situation for both the insurance company and the elderly generation by striking a profitable deal for insurance company and reasonable premium for elderly looking for cover against risks associated with old age.

The process starts by taking the information from the insured person. This information is obtained from a standard form that is used by the insurance company. This form contains different sections such as social, medical, self-sufficiency and socio-economic. And each section is also containing a set of information. Now the expert system generates the various measures such as: social index, health index, self-sufficiency index and socio-economic index used by the insurance company. These qualitative measures are quantified and converted into linguistic variables with corresponding membership functions. For example, the social index for the information section 1st is given by [8]:

\[
X_1 = \frac{\left[ \sum_{i=1}^{l} \sum_{j=1}^{l'} W_{ij} \Delta_{ij} \right]}{l}
\]
where $W_{ij}$ is the weightage or impact factor given to the $j$th information of the $i^{th}$ section, and $\Delta_{ij}$ is a 0-1 variable, where $\Delta_{ij} = 1$ if there is any deviation/difference in the information furnished by the insured person and the one obtained by the auditor, 0 otherwise. It is worthwhile noting that the information that is crucial in deciding the settlement of the claim is given higher weightage/impact factor. Also all the weights for a set of information $i^{th}, \sum_{j=1}^{l} W_{ij}$ add to unity. Similarly, the values of the other inputs can be determined. The normalized values of these measures are used as inputs to the expert system. The degree of membership corresponding to a value of input is determined by the use of triangular membership functions because of their simplicity and good result obtained by simulation. These membership functions are designed on the basis of available information.

Fig. 1 shows the definition of the fuzzy sets of the input and the output functions. A rule base is then constructed which will be based on all the applicable input parameters. For each decision several rules are fired. Table 1 shows a sample rule base for the system under consideration. These rules result in an aggregate fuzzy set that represents a particular decision regarding the processing of the claims. This fuzzy set is then converted into a crisp number, which depicts the degree of suitability of the decision regarding the processing of the claims. The rules aggregation is done using fuzzy centroid algorithm. Mamdani implication is used to represent the meaning of “IF-THEN” rules. In this context, the statement “if X is A then Y is B” or $A \supseteq B$ results in a relation $R$ such that $
abla_{X,Y} = \min(\nabla_{X}(X), \nabla_{Y}(Y))$.

![Membership functions of inputs and outputs functions](Image)
Table 1. Table for input parameter and corresponding output value.

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Example

For the purpose of illustration, we consider that the insurance company uses four inputs – social index $X_1$, socio-economic index $X_2$, self sufficiency $X_3$ and health index $X_4$.

(1) Input. Value of the base premium = 5,000 Rs.

(2) The values of the inputs of the insured person have to be evaluated, $X_1 = 0.40; X_2 = 0.70, X_3 = 0.60$ and $X_4 = 0.70$(say).
(3) Fuzzification of the crisp values of inputs. Through the use of membership functions defined for each fuzzy set for each linguistic variable (Figure 1), the degree of membership of a crisp value in each fuzzy set is determined as follows:

\[
\begin{align*}
\mu(x_1)_L &= 0.22 & \mu(x_1)_M &= 0.33 & \mu(x_1)_H &= 0 \\
\mu(x_2)_L &= 0 & \mu(x_2)_M &= 0 & \mu(x_2)_H &= 0.667 \\
\mu(x_3)_L &= 0 & \mu(x_3)_M &= 0.33 & \mu(x_3)_H &= 0.22 \\
\mu(x_4)_B &= 0 & \mu(x_4)_F &= 0 & \mu(x_4)_G &= 0.889
\end{align*}
\]

(5) Fire the rule bases that correspond to these inputs. Based on the value of the fuzzy membership function values for the example under consideration, the following rules apply:

Rule 24: If X is LOW, X is HIGH, X is MEDIUM and X is GOOD then Y is a MODERATE RISK (MR).

Rule 27: If X is LOW, X is HIGH, X is HIGH and X is GOOD then Y is a MODERATE RISK (MR).

Rule 51: If X is MEDIUM, X is HIGH, X is MEDIUM and X is GOOD then Y is a MODERATE RISK (MR).

Rule 54: If X is MEDIUM, X is HIGH, X is HIGH and X is GOOD then Y is an LOW RISK (LR).

(6) Execute the Inference Engine. We use the “root sum squares” (RSS) method to combine the effects of all applicable rules. The respective output membership function strengths (range: 0-1) from the possible rules (R1-R81) are:

“HIGH RISK” = \[\sqrt{\sum_{r=1}^{R} (\mu_r)^2}\] = 0

“MODERATE RISK” = \[\sqrt{\sum_{r=1}^{R} (\mu_r)^2}\] = \[\sqrt{(0.22)^2 + (0.22)^2 + (0.33)^2}\] =0.4535

“LOW RISK” = \[\sqrt{\sum_{r=1}^{R} (\mu_r)^2}\] = \[\sqrt{(0.22)^2}\] =0.22

(7) Defuzzification. We use “fuzzy centroid algorithm” for defuzzification.

\[
\begin{align*}
&= \int_{0.32}^{0.46} 4(x - 0.35x) dx + 0.460.740.45x.xdx - 0.740.784x - 0.85x dx + \\
&0.780.9722 x.xdx - 0.9716.67x - 1.xdx + 0.350.464x - 0.35dx + 0.460.740.45x.dx - 0.740.784x - 0.85dx + 0.780.970.22 x dx - 0.9716.67x - 1dx \\
&= (0.011+ 0.045+ 0.011+0.318+ 0.003) / (0.0255 + 0.074 + 0.015 + 0.0363+ 0.004) \\
&= (0.0958) / (0.1549) \\
&=0.618
\end{align*}
\]
Fig. 2 shows the shaded area and the crisp output of 0.618. The crisp output belongs to the set of MR more than the set of LR or HR (as evident from its membership function).

Hence, the customer will pay

$$\text{premium} = \text{base premium} + 0.45 \times (1 - \text{crisp output}) \times \text{base premium}$$

$$= 5000 + 0.45 \times (1 - 0.618) \times 5000$$

$$= 5000 + 859.50$$

$$= 5859.50 \text{ Rs.}$$

(8) Output of the decisions of the expert system.

4. Conclusion

The conditions listed above are merely intended to illustrate common disorders with increased age. They demonstrate the fundamentally different nature of underwriting practice. Yet persons affected by chronic diseases in old age are always anchored in a larger social and biographical background. The biographical background describes key variables in an individual's personal life history, career and marital status that continue to have repercussions well into old age. The social background encompasses not only personal factors but also economic circumstances and the health insurance system. All these factors impact life expectancy and quality of life.
5. References


Authors

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