JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue

JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)

An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Applications of Operations Research in Insurance Risk Management

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Abstract: This paper explores the use of operations research in the insurance industry. Our research has attempted to point out the various approaches of operations research that can be used to solve insurance risk management related problems. Having provided a general overview of all the techniques applied, we then focused on the three most famous OR techniques, which are: Linear Programming, Goal Programming, and Monte Carlo Simulation. These techniques are explained in detail, their areas of application along with their limitations associated. Discussion of our findings concludes the paper.

***Index Terms*- Operations research, insurance industry, insurance risk management, applications of operations research.**

I. Introduction

Risk Management involves analysing exposure to risk and devising strategies for handling it. Risk management is a best practice approach. It aims to identify the most important risks and identify how to minimize financial losses or address the future goals.

A key subpart of risk management is risk mitigation. This involves preparing for and reducing the effects of threats faced by an enterprise. Risk assessment frameworks (RAFs) are a commonly used tool for risk mitigation. By utilizing consistent risk assessment and reporting methods, a RAF can help mitigate risk. An insurance policy mitigates and transfers' risk. It refers to the act of providing indemnity or coverage for harm as per the contract. It refers to the financial and legal protection against potential future harm. Individuals and companies rely on it to manage their risks. Two-party contracts allow financial risk to be transferred from one party to another.

The Insurance industry is said to be increasing at a significant rate. The insurance industry is one of the most competitive and unpredictable sectors of the economy. It immediately conjures up images of danger. As a result, statistics have always played a role. The sector has seen a dramatic revitalization as it has explored more markets and methods, which has allowed them to develop more products to protect against crime, diseases, etc., as there has been a growing need in health care, pension, and other welfare areas. Insurance companies use Artificial Intelligence, Big Data Analytics, and Block Chains to transform their IT systems.

Operations research, as the name suggests, comprise of operations and research. Operations research helps in problems that are related to conducting and coordinating the operations. Operations research is an analytical method that helps in problem-solving and decision-making that is useful in the management of organizations. It breaks down complex problems into essential components and then solves them using various techniques. As such, Operation Research can be defined as the application of scientific methodology to operations management.

The research paper's key objectives include:

1. Exploring how insurance is a part of the risk management process.
2. Discussing how operations research is applied to insurance industry and understanding their application.
3. Reviewing OR based solutions developed in order to solve problems and gaps in the insurance industry.
4. Explaining the most commonly applied methods and discussing the limitations pertaining to them.

II. Literature review

A number of studies particularly specific to risk and risk management have been conducted throughout the years: AH Willet (Economic Theory Of Risk and Insurance) was one of the first authors to make an attempt to define risk. Willet claimed that risk is an impartial concept despite being related to subjective uncertainty. Frank H. Knight (1921) developed the concept of risk. It was his main objective to identify what features uncertainty identified as a risk should possess in

comparison with uncertainty in the strict sense. A broad detailed view of risk management identification and the process of analysing it for a solution has been aptly described in "Operation Research in Risk Management in strategic foresight" by (Nieberg).

When talking about literature specific to Operations research and its applications in the insurance industry; The application of OR techniques have been studied in a number of studies. A few examples are Turban (1972), Fabozzi and Valente (1976), and Ledbetter and Cox (Ledbetter, 1977). The studies reported on the results of surveys conducted among large companies, including some insurers; Turban discusses the outcomes of a national survey covering the activities of the OR departments in companies whereas Fabozzi and Valente showed how mathematical programming techniques may be used to solve a wide range of business problems by using results of a survey to provide partial and tentative answers to their questions. The McCahan Foundation annotated bibliography (Wade, 1970) speculates on the usefulness of other OR literature.

Many studies have examined the interaction between OR techniques and the insurance industry. The general approach has been twofold:

a) studies directed at an insurance audience: Examples include the studies of Zubay (1965) (1969), and Denenberg (1968); which is an incredibly informative and authoritative review on how OR could help the world of business
b) studies directed at an OR audience: Examples include (Sutton, 1965), (Halmstad, 1974), and (Jewell, 1974).

The work by Haehling von Lanzenauer and Wright (1991) is a great contribution to the literature as talks about operational research uses in insurance issues within the wider context of risk management. With appropriate references to actuarial science, it discusses application from both the insurer's and policyholder's perspective. Patrick I Brockett and Xiaohua (I, 1995) explain quantitative reasoning to insurance risk management and provide detailed descriptions of the various methodologies that they believe are used in the field. The paper has set a general discussion regarding the developments and trends in the operation research and insurance. Previous reviews had been organized according to their applications in the insurance industry in (Shapiro). As a follow-up to (Shapiro), Zubay (1965), and Mohit's (2019) work, we compiled a list of the numerous techniques available and further outlined the areas of industry in which such techniques have been applied to:

III. Methods and their applications

1. Linear programming

Upon reviewing multiple research papers, we found that linear programming can be applied to several areas and problems in the insurance industry, some of these include:

- Life Insurance Purchases (Shapiro): Optimal blending of various types of life insurance policies and other investments is a perennial problem in the sale of life insurance. A linear programming model was shown to be useful in solving this problem in (Schleef, 1980) .
- Profits of Property and Liability Insurers (Shapiro): Hofflander and Drandell (1969) proposed a linear programming model for maximizing profits of a property and liability insurance company under operational and regulatory constraints. This model was designed to determine the best allocation of assets to maximize profits.
- The linear programming models developed by (Conwill, 1991) enable policyholders to maximize their value in decisions involving life insurance products and asset investments. Conwill discusses the methods for developing linear programming models for insurance problems, how to solve the problems computationally, and how to interpret the results of the computations.
- Investment portfolio development.

2. Goal programming

Researchers have used goal programming which is an analytical approach to minimize the possibility of not reaching the goals and finding optimal balance between multiple objectives.:

- Charnes and Cooper (1977) established the fundamentals of goal programming and developed a strategy that can handle a variety of incompatible and incommensurable goals
- Insurance Agency Management
- A study by Gleason and Lilly (1977) examined goal programming as a tool used by property and casualty insurance agencies as they made decisions regarding the number of insurers to represent, cost-reducing efforts, and adding commercial lines.
- Profit Maximization in Property and Liabilities Companies: Although Klock and Lee (1974) asserted that aspects of linear programming are not practical in practice. As an alternative, they suggested goal programming.

3. Monte Carlo stimulation

Monte Carlo Simulation is a mathematical technique for measuring risk for quantitative analysis and decision-making. The tool shows all the possible outcomes and probabilities; it shows the extreme impacts of our decisions. A large number of aggregated claims can result in large losses for the company (Shaul Bar- Lev, 2018):

- Richard L. Norgaard took a financial statement of assets and premiums of a property and liability insurance company as a model in order to perform the Monte Carlo method and concluded that there are three types of results: investment, underwriting, and combined investment and underwriting (Norgaad, 1964).
- Determining frequency distribution of the annual claim cost of a given group of lives for a given year.

- Reinsurance rate calculation with non-proportional retention limits under several assumptions.
- Calculating insurance mortality rates and their confidence intervals.

4. Game theory

Game theory is a study of the strategic interaction of rational decision-makers through mathematical models. Williams (1960) discussed the use of pure strategies to evaluate insurance consumption alternatives. The analysis focused on the loss in utility associated with the decision whether or not to purchase fire insurance. Many insurance settings have found game theory useful:

- Life Insurance Underwriting: Lemaire (A Game Theory Look At Life Insurance Underwriting, 1980) considered the problem of insurance underwriting in the context of a game between an insurer (player 1) and a potential policyholder (player Z).
- Cost Allocation: Lemaire (1984) examined how the theory can enable insurance company in allocating expenses to its various departments when economies of scale are present.
- Insurance contract negotiation (Kihilstrom, 1982).
- A best-case scenario for insurance purchase when among uninsurable risks and mandatory insurance (Schulenburg, 1986) ..
- Process control for mutual insurance (Tapiero, 1983).
- Settlements of liability insurance claims without court intervention (Fenn, 1990).

5. Markov chain theory

Markov chains are stochastic models that describe a sequence of possible events in which the probability of each event is dependent only on the previous event. It can be applied in the industry to solve or demonstrate:

- Working Life Tables: Hoem (1977) argued that working life tables can be generated using the theory of continuous-time Markov chains because they derive from the dynamics of labour force participation. In this case, transitions are related to death, entry into the labour force, and separation from the labour force.
- By using Markov chain modelling, Haehling von Lanzenauer (1973) showed that policyholder distributions are consistent with claims decisions based on the difference between premiums paid during the first year following an accident.

6. Dynamic programming

Unlike linear programming, dynamic programming is able to accomplish maximum efficiency by interconnecting sequential decisions over time, especially in a multistage environment. Application areas include:

- Dynamic Life Insurance Programming: The study by Belth (1964)was one of the earliest attempts to apply dynamic programming to the problem of choosing an optimal life insurance program. The study was naive by today's standards. However, the interrelationship of the variables is as relevant today as it ever was.
- Risk Management: Using dynamic programming to aid risk managers in equipment replacement decisions where minimizing losses is the aim was discussed by Lilly and Gleason (1977)

7. Other methods conferred in numerous literatures include:

- Chance constrained programming
- Fuzzy Set Theory and Fuzzy Programming
- Critical Path Scheduling
- Inventory Models
- Portfolio Selection
- Statistical Quality Control
- Work Sampling
- Network models
- Queuing Theory

IV. Detailed methodology

Linear programming

This mathematical approach finds optimum solutions to problems whose solutions can be expressed as linear equations or inequalities. When a real-world problem can be accurately modelled by the mathematical equations of a linear program, the method will find the best solution. A linear program must, by definition, consist of linear equations and inequalities. Variables in linear programs are the quantities that need to be determined in order to solve the problem. Essentially, a linear programming problem will involve the maximization or minimization of a numerical value. There are constraints that determine the range of possible values for variables in linear programming.

To solve a linear programming problem, you find the optimum value (largest or smallest, depending on the problem) of the linear expression called the objective function;

Max/ MIN Z = cTx; subject to constraints expressed as inequalities; $a1x1 +/- a2x2 +/-....=< b1, a3x1 +- a4x2 +/-....=< b2$

The a's, the b's, and the c's represent constants based on capacities, needs, costs, profits, as well as other requirements and restrictions. The method is grounded on the assumption that the various relationships between demand and availability are linear. It is necessary to find the solution to the system of linear inequalities in order to solve this problem. By substituting the values of x in the equation that defines Z, the objective function is determined.

Finance is managed using linear programming in insurance. Models for profitability, capacity, and regulation have been created in insurance management. Throughout the years, the method has been used to model and calculate efficiently liability risks, form a portfolio mix to multi-grow an insurance company, plan life insurance purchases, etc. It is used to maximize policyholder values and make decisions about life insurance purchases. LP methods can be applied in a number of financial areas, including capital budgeting, portfolio management, duration matching, and immunization. A number of actuaries and insurance managers also find these applications useful.

Limitations:

- Linear programming is not very efficient when there are more variables in a situation.
- There are many assumptions in linear programming that are inaccurate or not realistic in a real-world scenario; linear programming makes no assumption about the economics of scale, which is completely incorrect in a real-world business scenario.

Goal programming

Goal programming is a method for balancing a trade-off between conflicting objectives while solving a multi-objective optimization issue. It's a method for determining the most "satisfactory" level of goal achievement. By rating or weighing several goals according to their value, a certain priority order is established.

The priority structure aids in the management of all goals that cannot be completed totally and/or concurrently in such a way that the most important goals are completed first, at the expense of the less important ones.

Goal Programming is assumed as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Goal programming performs three types of analysis:

- Determine the resources required to fulfil a desired set of objectives.
- Determine the degree to which the goals may be met with the available resources.
- Providing the most satisfactory solution under a variety of resource constraints and goal priorities.

The objective of the goal programming approach is to minimize the deviations from its stated goals. There are two variables associated with each goal which are basically constraints, which is the overachievement and the underachievement deviation. This helps in measure how well the goal is accomplished. The goals are well achieved if the variables are closer to zero. However, both the variables cannot be zero at the same time as a goal cannot be overachieved and underachieved at the same time.

After deviational variables have been assigned for the goals, then the next step is to find the objective function. It is usually a linear function with deviational variables. Then the weights are assigned to the deviational variables which will indicate the importance of the goal in the decision making. The main objective is to minimize the weighted sum of deviations to accomplish the best overall result.

After this, the constraints are developed. It is done just like as in Linear Programming but here the equations are formed by giving priorities to deviations. Then at the end, the model will be formed by forming a goal equation for each goal and the objective functions will be as follows:

Minimize $Z= Q_1(d_1) + Q_2(d_2) +Q_3(d_3) +Q_4(d_4)$
Where Q_1, Q_2, Q_3, Q4 represent the goals based on the priority level 1,2,3,4 respectively and d implies the positive and negative deviations the goal at various levels.

Limitations:

- The construction of model while using the goal programming approach takes more time and thought than other methods.
- Decision makers need to be more involved, that is, to establish aspiration levels and weights.
- Subjectivity relating to weights given to priority levels instead of goal deviations may be of concern.

Monte Carlo simulation:

Monte Carlo Simulation is a mathematical and methodological method for calculating risk in order to do quantitative analysis and make decisions. It demonstrates the extreme possibilities of the influence of our decision by listing all possible outcomes and probability. The possibility of a significant number of aggregated claims resulting in large losses for the organisation is the greatest

difficulty that an insurance company can face. The analysts employ a separate set of random variables from the probability function in Monte Carlo analysis. It is recalculated over and over, with recalculations ranging from thousands to tens of thousands of times.

Monte Carlo simulation in portfolio management for insurance companies: In this scenario, the model represents a property and liability insurance company's financial statement of assets and premiums. In this case, the underwriting area is a major constraint. The usage of aggregate income, asset, and premium values serves as a limitation as well. Because the technique's usefulness cannot be established if it is applied only to one organisation, aggregate values must be used.

Intensity-based models frequently employ Monte Carlo simulation. Despite the fact that a model is given analytical solutions, simulation is employed for pricing and risk management since it involves path dependent cash flow streams. Monte Carlo simulation is mostly used by portfolio managers and financial advisors to analyse the impact of risk and portfolio management on investments. It's used to forecast cash flows and risks associated with new product concepts.

Limitations:

- Extreme events, such as a financial crisis, are not taken into account in Monte Carlo simulations.
- The returns predicted by this model are frequently erroneous. Because this method uses a random set of variables, it does not accurately reflect the genuine amount of success because success is not defined correctly.
- Bad outcomes will be produced as outputs if poor parameters and constraints are used in the model.

V. Ultimate Findings and Conclusions:

Insurance companies can achieve their goal of minimising risk and generating profit with the help of operation research. Many operations research approaches are available as mentioned previously in the paper.

According to our research, linear programming is one of the most widely utilised techniques. It assists companies in allocating resources based on constraints or parameters in order to reach their objectives and aims. Goal programming involves setting goals and identifying variables, then solving to minimise the deviation between them to become as close to the goal as achievable. Goals such as profit maximisation, loss minimization, and client retention are solved in the insurance industry to keep everything in balance, because if a firm simply concentrates on profit, it may lose sight of customer loyalty and service, thus it is vital to create goals accordingly. Monte Carlo Simulation is primarily employed in inventory-based models. It's utilised to pick a course with the least amount of risk or the most benefit. It is a computer-based method since there are several recalculations that must be performed using various sets of random variables and probability functions.

Even though the insurance industry uses OR methods, it is not fully utilised. There are only a handful techniques employed. Continuous efforts have been made in the areas of technology and operations research. Because the insurance industry is predicted to grow at 15% over the next five years, OR approaches can be used effectively to gain a competitive advantage.

REFERENCES

Belth, J. M. (1964). Dynamic Life Insurance Programming. *Journal of Risk and Insurance*.

Braun, H. (1978). Stochastic Stable Population Theory In Continuous Time. *Scandanavian Acturial Journal*, 185-203.

Charnes, A. C. (1977). Goal Programming and Mulitple Objective Optimizations: Part 1. *Europian Journal of Operational Research*, 39-54.

Christoph Haehline von Lanzenauer, D. D. (1991, January). Operational Research and Insurance. *European Journal Of Operational Research*.

Conwill, M. (1991). A Linear Programming Aproach to Maximizing Policyholder's Value. *Acturial Research Clearing House*, 1-102.

Fenn, P. V. (1990). Bargaining Behaviour by Defendant Insurers: An Economic Model. *The Geneva Papers on Risk and Insurance Issues and Practice*, 41-52.

Frank J. Fabozzi, J. V. (1976, November 1st). Mathematical Programming in American Companies: A Sample Survey. *INFORMS Journal on Apllied Analytics*, 93-98.

Giesecke, K. (2011). Monte Carlo Algorithms for Default Timing Problems. *INFORMS*.

Gleason, J. M. (1977). 'A Goal Programming Model For Insurance. *Decision Sciences*.

Gleason, J. M. (1977). 'A Goal Programming Model For Insurance Agency Management. *Decision Sciences*, 180-190.

Halmstad, D. G. (1974, October). Actuarial Techniques and Their Relations to Noninsurance Models. 942-953.

Herbert S. Denenberg. (1968, March 1st). *The Journal of Risk and Insurance*, 159-163.

Hoem, J. M. (1976). A Markov Chian Model of Working Life Tables. *Scandanavian Acturial Journal*.

Hoem, J. M. (1977). A Markov Chain Model of Working Life Tables. *Scandanavian Actuarial Journal*.

Hofflander, A. D. (1969). A Linear Programming Model of Profitability, Capacity, and Regulation in Insurance Management. *Journal of Risk and Insurance*.

I, P. (1995). *Operations Research In Insurance*.

Jewell, W. S. (1974). Operations Research In The Insurance Industry: I. A Survey Of Applications. *Operations Research*.

Kihilstrom, R. a. (1982). Risk Aversion and the Negotiation of Insurance. *Journal of Risk and Insurance*, 372-387.

Klock, D. S. (1974). A Note on Decision Models for Insurers. *Journal of Risk and Insurance*, 537-543.
Knight, F. H. (1921). Risk, Uncertainty and Profit.

Ledbetter, W. N. (1977, February). 'Are OR Techniques Being Used?' Industrial Engineering.

Lemaire, J. (1980). A Game Theory Look At Life Insurance Underwriting. *Astin Bulletin*, 1-16.

Lemaire, J. (1984). An Application Of Game Theory: Cost Allocation. *Astin Bulletin*, 61-81.

Mohit Samal, N. A. (2019, October 20th). Operations Research In Insurance. *International Journal of Scientific & Engineering Research*, *10*(10).

Nieberg, S. M. (n.d.). *Operation Research in Risk Management in strategic foresight*.

Norgaad, R. L. (1964). A Monte Carlo Simulation in Insurance Company Portfolio Management. *American Risk and Insurance Association*.

Schleef, H. J. (1980). Using linear programming for Planning Life Insurance Purchases. *Decisions Sciences*, 522-534.

Schulenburg, J. G. (1986). Optimal Insurance and Uninsurable Risks. *The*, 5-16.

Shapiro, A. (n.d.). Applications of Operations Research Techniques in Insurance. *1986*.

Shaul Bar- Lev, A. R. (2018). Monte Carlo Methods for Insurance Risk Computation.

Sutton, R. (1965). Operational Research On Actuarial Work.

Tapiero, C. Z. (1983). Optimal Investment-Dividend. *Scandinavian Actuarial Journal*, 65-76.

Turban, E. (1972, June). A Sample Survey of Operations-Research Activities at the Corporate Level. *20*, 708-721.

Wade, R. C. (1970). Operations Research and Insurance Applications: An Annotated Bibliography. *McCahan Foundation*.

Willet, A. H. (n.d.). Economic Theory Of Risk and Insurance.

Williams, C. A. (1960). Game Theory And Insurance Consumption. *Journal of Risk and Insurance*, 47-56.

Zubay, E. (1965). Feasibility Study Of Operations Research In Insurance. *Journal of Risk and Insurance*, 325-336.

Zubay, E. (1969). The Role Of Operations Research And Life Insurance. *Society Of Chartered Life Underwriters*, 55-61.

ZUCKERMAN, D. (1985). Optimal Unemployment Insurance Policy. *Operations Research*, 263-76.