# Operations research in insurance

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**ABSTRACT:**

*In this paper, we explore the use of Operations research in the Insurance industry, an industry which is said to grow at 15% in the next five years. Insurance industry is one of the most important sectors of the economy. Insurance sector is ripe with endless possibilities of model building. Our objective of the study was to identify the different techniques used in Operations Research and link them to those used by the Insurance sector. We identified the needs and issues in the insurance industry and how efficiently can they be solved with the help of OR. We have mainly focused on the three most frequently used techniques in Insurance; Linear Programming Problem, Goal Programming and Monte Carlo Simulation. There has been no use of quantitative data for analysis in this research paper.*

*Keywords: Operations research, Insurance, Linear programming problem,Monte Carlo Simulation, Goal programming*

## INTRODUCTION:

Insurance industry is said to grow at 15% for the next five years. Insurance sector has seen a dramatic revitalization as it has explored new markets and distribution methods, developed new products to protect against crime, disease and auto accident, and concerned itself with the growing needs in the health care, pension and other social welfare areas. Innovation through new technologies is a key driver of change in the financial sector and this has led to immeasurable efficiency gains, even though these changes can initially be accompanied by uncertainty and doubt. The insurance sector is no exception to such developments, with possibilities of new methods of service provision as well as greater opportunities for data collection and fraud detection that can lead to better risk identification and mitigation measures. (Jewell, 1974)

The insurance industry is regarded as one of the most competitive and less predictable business spheres. It is instantly related to risk. Therefore, it has always been dependent on statistics.

Despite constant liberalization of the current insurance industry, a major part of the population still does not believe in any insurance. This is majorly because the many challenges associated with the sector including a split ecosystem, regulatory uncertainty, and disjointed data continue to remain specific. With the constant developments in technology and recognition of operations research in the last few years, most of the issues have been addressed. Advanced analytics, Block chain technology and many operations research techniques have acted as catalyst to enhance the importance of insurance.

Operations research as the name suggests comprise operations and research. Problems related to conducting and coordinating the operations requires operation research. Production of goods and activities related to it, like procurement and consumption of raw materials, assigning the work, inventory management, transportation and distribution of goods are dealt by operations management.

Research on the other hand, is used to provide a systematic procedure to address a situation. A scientific method consisting of problem formulation, assumption, data collection, mathematical solution and interpretation is followed by research. Therefore, Operation Research can be defined as the techniques of scientific methodology used in areas of operations management.

Various uses of Operations research are:

- Scheduling airlines, both planes and crew
- Decision making of the appropriate place to site new facilities like factory or warehouses
- Water flow management from reservoirs
- Identification of possible future development paths for parts of telecommunications industry
- Establishment of health services related information search and appropriate systems to supply them
- Identification of the strategies that companies adopt for their information systems

This research paper aims at achieving the knowledge on the importance of Operations research and doing a detailed study on some of the techniques of operations research used in Insurance sector.

**OVERVIEW OF THE INDUSTRY:**

Importance of insurance in business:

Uncertainty of business loses is reduced - Huge number of properties are employed in the business industry. A slight negligence can cause a great loss to property. Therefore, if the property is not insured, uncertainty will be maximum and no one would like to invest such a huge amount of money in the business.

Business efficiency increased - With the assurance that the businessmen has for the loss he incurs that he will receive a certain amount of money for the unfortunate event. Therefore, he will have a peace of mind and will be able to focus more on the profitability of the business.

Enhancement of credit - The insurance policy can be pledged as collateral to borrow loans. Chances of insured people getting loans are more since it is sure that the repayment will be carried out.

Welfare of employees - The employers get group insurance policies for their employees which is the cheapest form of insurance for employers to fulfil their responsibility and the employees will work at maximum capacity. (Iedunote)

Recent happenings in the insurance industry:

India's insurance industry is improving efficiencies by the use of new age technology. Example: The destructive floods in Kerala required a large number of people to claim their insurance. Reliance General Insurance deployed a video conversation feature which helped them transfer the claims within 3 days.

Insurance companies are using Artificial intelligence, big data analytics and block chains to transform their IT systems.

Insurance companies have launched mobile apps to make it easier for their customers to transact with them. The claims can be transferred within a few hours. They are trying to move towards paperless claims. (Sangani, 2019)

**Research Objectives:**

1) To understand the importance of Operations Research in Insurance.
2) To obtain some indication of the extent to which application of these techniques are made in the insurance company.
3) To explore the milestones achieved by the Insurance sector in terms of technology and data science
4) To identify the limitations of the techniques used in the Insurance sector
5) To outline the future trends of Operations research in Insurance

**Research Methodology:**

For our research paper, we have done a secondary research. This research paper is based on the evaluation and understanding of various previously published research papers, news articles, and blogs.

**Literature Review:**

The field of OR is constantly growing and the applications of OR techniques in the Insurance sector are expanding rapidly. There are various areas of insurance where OR is used extensively:

1) Underwriting: Unlike most businesses, the insurance industry does not automatically serve every potential customer brought in by the salesman. The responsibility of risk selection belongs to the underwriting department and the underwriter has ultimate jurisdiction over the terms under which a contract may be issued. Underwriting is the credit manager at the sales counter of insurance.
2) Claims: Claims is the most important function peculiar to the insurance company. It is the last point at which one can reduce losses in terms of paid-out claims. After coverage is verified, the potential value of the claim must be determined by the specialist.
3) Engineering, legal, medical and other support function: There are various support functions that are particular to each branch of insurance; fire, boiler and elevator lines require engineer-inspectors, health insurance requires both a staff with medical training as well as detailed interactions with health organizations. (Jewell, 1974)

Operations Research is therefore used in many components of insurance, right from identification of participating parties, the premium, the coverage period, loss event covered to the amount of coverage. Although, there are a few fields of insurance where OR is not yet applied.

As mentioned previously, Operations research is an analytical method of problem-solving and decision-making that is useful in management of organizations. In OR, complex problems are broken down into basic components and then solved by various techniques.

There is a process followed regardless of which technique is used. The process is as follows:

1) Identifying the problem that needs to be solved.
2) Constructing a model around that problem that resembles the real world and variables.

3) Using the model (from the technique used) to derive solutions to the problems
4) Testing the optimality of the solution achieved and analyzing it.
5) Implementing the solution. (Tech Target, 2019)

Using Operations Research can help companies achieve complete datasets, consider alternatives, predict all possible outcomes and estimate risk.

There are various techniques of Operations research. Some of them are:

1) Linear Programming Problems
2) Simplex method
3) Transportation model
4) Assignment model
5) Queuing theory
6) Game theory
7) Monte Carlo Simulation and many more…

Use of Operations Research in Insurance Industry:
(Patrick L. Brockett, 1995)

- Linear programming is used for financial management in insurance. It is used to determine profitability, capacity and regulating problems in insurance management. It is also used for maximizing policy holder values and decision making in life insurance purchases.
- Quadratic programming is used for maximizing the expected portfolio return and portfolio analysis.
- Integer programming such as network flow models are used in insurance industry for financial planning and cash management.
- Dynamic programming is used in insurance companies to maximize the expected utility of the dividends paid.
- Chance constrained programming is used by insurance companies to maximize their earnings from underwritings and from their investment income.
- Game theory has been used for cost allocation and life insurance under writing of insurance companies. It is also used for negotiation of insurance contracts and provides for an optimal purchase of insurance which are mandatory or for uninsurable risks.

Since the main objective of the research paper is to understand the importance and use of OR in the field of insurance, we aim to only focus on the techniques used in Insurance.

The techniques which are explained in our research paper are:

- Linear Programming Problem
- Goal Programming
- Monte Carlo Simulation

LINEAR PROGRAMMING PROBLEM:
Linear Programming is one of the most important technique used in Operation Research for solving and allocating scarce resources and decision making. Sometimes one seeks to optimize, either by maximizing or minimizing, a known function which could be profit or loss or any output, subject to a set of linear constraints on the function. Constraints are risk, expense, capital requirement, legal bounding etc., while goals are issuing new policy, profit maximization etc.

The uses of LPP in insurance are:
- Distributing advertising budgets among various media to obtain sufficient coverage.
- Developing investment portfolios
- insurer profits maximization
- Casualty reinsurance problems
- Allocating funds for sales expansion by creating new agencies, selecting agency locations, placing new agents and developing new schemes or insurance products.
- maximize profit by allocating funds in the most efficient way. To Maximize the present value for marginal tax rate for future cash flow loan and investment. (Shapiro)

Example: Let's say an Insurance Company named ABC is selling 2 policies. One is Life Insurance Policy and one is Fire/ Any General Insurance Policy. It costs the company Rs 300 in issuing Life insurance policy and Rs 500 in issuing the General Insurance policy at the Mumbai branch. The Mumbai branch has a budget of spending at most Rs 8000. If the company ABC can make a profit of Rs 500 in Life Insurance policy and Rs 700 in General insurance policy, risk in life insurance is 9 while in general insurance is 5 while the company wants to maintain an average risk factor of 7. How many of each Policies should be sold for the firm to get the maximum profit?

| | Insurance | Life | Fire | | resoursces used | available |
|---|---|---|---|---|---|---|
| Objective | Profit Per Policy | 500 | 700 | | | |
| | | | | | resoursces used | available |
| Constrains | Cost for Issuing | 300 | 500 | | 8000 < | 8000 |
| | Risk | 9 | 5 | | 7 < | 7 |
| | | | | | | |
| | No. of Policy to Aim | 10 | 10 | | profit | 12000 |

Limitations: Linear Programming is not very efficient when more variables are there in the situations. Many assumptions are there in linear programming which are not accurate or realistic in real world scenario, like no economic of scale is an assumption in linear programming which is completely wrong in any given real-world business scenario. This makes usage of linear programming less useful.

GOAL PROGRAMMING

Goal Programming is an analytical approach which is focused on minimization of the non-achievement of the goals. All goals cannot be met at the same time; it always comes at the cost of other goals. Therefore, goal programming attempts to reach a satisfactory and optimum level of multiple objectives. The construction of linear programming and goal programming is almost the same. The only difference between the two is that linear programming attempts to minimize or maximize the objective function but goal programming attempts to only minimize the deviations between the target values of the objectives and the realized results. There are two types of goal programming, weighted goal programming and primitive goal programming. In weighted goal programming, the weights are assigned to the goals according to their relative importance and then it uses solution to minimize the weighted sum of the deviations from the targets. In primitive goal programming the weights are given to the goals according to the choice of the decision maker of what is important according to him. In this case the decision maker knows exactly which goals to achieve. (Karagul, 2018)

In goal programming, each goal is formulated as constrains, two variables are set for each goal overachievement deviation and underachievement deviation. These two variables describe how well a goal is achieved; each deviation variable should be close to zero for better achievement of goal while both cannot be zero at the same time because it will be infeasible. After setting variable for goal an objective function has to be created, an objective function is a goal programming formulation usually a linear function in deviational variables. Goal programming model

for an insurance company can be used in calculating profit, current asset returns, Maximize lifetime customer value, and legal bounded goals. While later it was also used for optimum asset allocation capital budgeting & agency management. (PATRICK, BROCKET, & XIAOHUA, 1995)

(PATRICK, BROCKET, & XIAOHUA, 1995)and (Karagul, 2018) explained its application as:

$$\min z = \sum_{i \in n}\left(d_i^+ + d_i^-\right), \quad \text{subject to} \quad \sum_{j=1}^{m}\left(a_{ij}x_j - d_i^+ + d_i^-\right) = b_i, \quad x_j, d_i^+, d_i^- \geq 0$$

Where $x_j$ is the decision variable for j=1,.....m: $a_{ij}$ represents the decision variable

coefficients; $b_i$ is the aspiration level; $d_i^+$ is the positive deviation variable from overachieving the $i^{th}$ goal and $d_i^-$ is the negative deviation variable from underachieving the $i^{th}$ goal for i=1,…,n. If the management is unconcerned about whether there is an overachievement of the target, $d_i^+$ can be omitted from the object function, vice versa. In other words, $b_i$ the aspiration level which is needed to be achieved is chosen for each of the objectives thus the undesired deviations from the given set of goals are minimized by using the achievement function z (total deviation function/object function). In Table 1 for different acceptable situations such as overachievement or underachievement of $b_i$ the deviation variables to be minimized are summarized.

| GOAL | ACCETABLE SITUTATION | DEVIATION VARIABLE TO BE MINIMIZED |
|---|---|---|
| $a_{ij}x_j <= b_i$ | Underachievement | $d_i^+$ |
| $a_{ij}x_j >= b_i$ | Overachievement | $d_i^-$ |
| $a_{ij}x_j = b_i$ | Exact achievement | $d_I^+ + d_i^-$ |

**Price Optimization in Goal Programming:**

Goal Programming is used to calculate optimal premium of a car insurance of a hypothetical portfolio of clients using statistical tools, price elasticity of demand and simple optimization algorithms to stimulate results. Through data mining and a program of optimization of the insurance premium, proposes a model of segmentation of clients according to the probability of retention of the customer segments or clusters and their sensitivity to changes in the price. It starts from the calculation of demand functions using GLM models to estimate the sensitivity to the price of the customers and then applies premium optimization algorithms. With this estimated demand function, the margin of profitability of the customer portfolio is

maximized while maintaining the retention of the customer portfolio. (Mayorga & Torres, 2017)

Limitations of Goal programming: A debated weakness is the ability of goal programming to produce solutions that are not Pareto efficient. Pareto efficiency is a state of allocation of resources from which it is impossible to reallocate so as to make any one individual or preference criterion better off without making at least one individual or preference criterion worse off.

MONTE CARLO SIMULATION:

Monte Carlo Simulation is a mathematical technical method that measures the risk for quantitative analysis and decision making. It gives all the possible outcomes and probabilities; shows the extreme possibilities of the impact of the decision we make. The greatest challenge that an insurance company can face is the risk of a large amount of aggregated claim that will lead to large losses for the company (Shaul Bar-Lev, 2018) .In Monte Carlo analysis, the analysts uses different set of random variables from the probability function. It is calculated again and again and the recalculations can be thousand to ten thousand times.

Monte Carlo simulation in insurance company portfolio management:

The model in this case is the financial statement of assets and premiums of a property and liabilities insurance company. The underwriting area is a major constraint in this problem. The use of aggregate values of income, assets and premiums also acts as a constraint. Aggregate values need to be used because otherwise the usefulness of the technique cannot be determined if applied only to an individual company. The alternative incomes are earnings on premium written and other from invested assets. For this model, it is a very difficult task to determine the value of incomes hence it is calculated using past data. Appropriate statistical methods should be used for the simulation of selected decisions. In the example given by Norgaard, 360 trials were used for each portfolio mix and this number was sufficiently normal to which different statistical tests could be implied (Norgaad, 1964)

Monte Carlo simulation is widely used in intensity-based models. Though analytical solutions are given to a model, simulation is used for pricing and risk management as it involves path dependent cash flow streams (kay giesecke, 2011). Mostly portfolio managers and financial advisors use Monte Carlo simulation to determine the impact of the risk and portfolio management of investments. It is used to estimate cash flows and the risks related to new product ideas.

**Limitations of Monte Carlo Simulation:** Monte Carlo simulation does not consider probabilities of extreme events such as a financial crisis. The returns estimated by this model are often unrealistic. This method takes random sets of variables therefore it does not convey the true level of success as success is not defined appropriately.

**FINDINGS:**

Operation Research has helped Insurance Industry grow. With the help of operation research, insurance company can achieve their goal by minimizing their risk and maximizing the profit. They can use many operation research techniques like Linear programming, Goal programming, Game theory, Quadratic programming, Chance-constrained programming etc. According to the research done, we found that Linear programming is one of the most commonly used technique in insurance, linear programming helps company allocate their resources according to their constrains or parameters to achieve their objective and achieve goals. In Goal programming goals are set and their variables are identified, and it is solved to reduce the deviation between them to get as close as possible to goal, goals can be underachieved or exact or overachieved. In insurance, goals like profit maximization, Loss minimization and customer retention are solved to get everything in balance, because if company only focuses on profit then they might drift from customer loyalty and customer service, therefore it is necessary to set goals appropriately. We also found out that Monte Carlo Simulation is mostly used in inventory-based models. It is used for choosing a path in which the impact of the risk is minimum or positive. It cannot be solved manually and a use of computer is extremely essential as there are re-calculations which have to be done again and again using different sets of random variables with probability functions. Even though Insurance sector is using OR techniques, they are not fully utilizing it. Only a few techniques are used. There is still a huge scope for improvement in this sector. There have been constant efforts regarding technology and Operations research. Since the Insurance sector is expected to grow at 15% in the next five years, they can effectively use OR techniques and build a competitive advantage as well.

**CONCLUSION:**

As quoted by Sir Charles Goodeves, Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control. The main objective of this study was to obtain some indication of the extent to which application of

these techniques is made in the insurance company. Based on the research done, it is evident that Insurance sector still has a lot of scope for improvement in the field of Operations Research. OR has been implemented in almost all sectors and is also being used in day to day life and business activities. There have been a few areas in Insurance where OR is still not applied.

Analytics is expected to play a great part in driving the insurance industry in the coming few months. The technology will enable insurers across the country to efficiently enable predictive analysis. Insurers can leverage analytics to make predictions about a person's probability of getting an ailment and therefore, timely suggest him to take necessary precautions. This can be done by implementing intelligent health analytics to a patient's medical history in order to predict the future health approach. The technology can even prove positive results for deciding the best course of action, in terms of identification of most effective treatments and drugs resulting in cost-efficient treatments.

**LIMITATIONS:**

Through the process of making this research paper, several challenges were encountered. Some of them are:

1) Lack of research papers on the topic.
2) Difficulty in acquiring quantitative data to test our models.
3) Paid access to some of the best research websites.
4) Advanced terms used in the research papers which are difficult to understand in layman terms.

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