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Mastering SP8: A Comprehensive Guide to Fundamental Concepts

INTRODUCTION

Insurance	A financial arrangement in which participants make payments in exchange for a commitment to indemnify certain types of losses.
Reinsurance	An arrangement where insurer transfers away a part of the risk to another company (known as reinsurer).
Written Premium	The total amount of premium received from policies for which cover commenced during a specific accounting period.
Earned Premium	The portion of written premium for which coverage has already been provided during a specific accounting period.
Unearned Premium	The portion of written premium for which coverage has not yet been provided and is deemed to relate to cover in one or more subsequent accounting periods.
Incurred Claims	The total of all claims paid plus the total reserves for outstanding reported claims (the total reserves for outstanding claims are also called case estimates).
Claims Handling Expenses	The expenses incurred in handling and settling claims. Also known as 'loss adjustment expenses' in the US.
Written Exposure	The total exposure that arises during a period.
Earned Exposure	The portion of written exposure for which coverage has already been provided.
Technical Reserves	The reserves held to cover the liabilities relating to insurance policies already written.
Reserves for Outstanding Reported Claims	The estimated reserves needed to settle all the claims reported to the insurer at an accounting date.
IBNR Reserve	The estimated amount that is needed to cover the claims for which accident events have happened but not yet reported to the insurer at an accounting date.
IBNER Reserve	The estimated amount that is needed to cover the changes in estimates of reported claims as at an accounting date.
Unearned Premium Reserve	A retrospective reserve held for premiums that have not been earned yet as at an accounting date.
Unexpired Risk Reserve	A prospective reserve required to cover the claims and claims handling expenses expected to emerge from an unexpired period of cover.
Claims Equalisation Reserves	A reserve maintained to smooth out fluctuations in claims experience over time.
Free Reserves	The excess of the value of assets of an insurer over the sum of its technical provisions and current liabilities.
Reporting Delay	The time gap between occurrence of a claim event and reporting the same to the insurer.
Settlement Delay	The time gap between reporting of a claim to the insurer and its settlement to the insured.

Short-tail line	A line of business where claims are generally reported and settled quickly.
Long-tail line	A line of business where claims take time (years or even decades) to be reported, assessed and settled.
Underwriting Income	The income earned by the insurer from its core insurance operations, also known as operating income.
Investment Income	The income earned by the insurer from its investment portfolio.
Accident Year	An aggregation method where only the loss transactions relating to the loss events that occurred during that period are grouped together.
Calendar Year	An aggregation method where all premiums and loss transactions that occur during a twelve-month period are grouped together.
Underwriting Year	An aggregation method where all premiums and loss transactions on policies written during that period are grouped together.
Reporting Year	An aggregation method where only the loss transactions relating to the loss events that are reported during that period are grouped together.

GENERAL INSURANCE PRODUCTS

Uberrima Fides	Principle of utmost good faith observed by parties of insurance contract.
Suretyship	Insurance to provide for the financial obligations of the insured, if the insured fails to do so.
Underinsurance	A situation when the sum insured is lower than the value of contents specified in insurance contract.
Discovery Period	A time limit within which claims must be reported to the insurer.
Deductible	An amount that the insured must pay before the insurer starts to pay.
Excess	Similar to deductibles, but does not reduce the maximum payout.
Salvage	Amount recovered from sale of insured items that become property of insurer after settling the claim.
Subrogation	An insurer, after paying claims, assumes insured's legal rights to recover the amount by third party.
Recoveries	Amount recovered to offset cost of claims. Includes salvage, subrogation, reinsurance recoveries, etc.
Lapse	A policy that when invited to renew, does not do so.
Cancellation	A cessation of the policy, which may involve partial return of premiums.
Underwriting	A process of assessing whether the risk is acceptable and, if so, determining the appropriate premium with the terms and conditions of the cover.
Claim Frequency	The number of claims in a period per unit of exposure.
Claim Severity	Average claim amount
Claims Made Policy	A policy that covers all claims reported to an insurer within the policy period irrespective of when the loss occurred.
Losses Occurring Policy	A policy that covers all losses that occurred within the policy period irrespective of when the loss is reported.

Risk Attaching Policy

A basis under which reinsurance is provided for claims arising from policies commencing during the period to which the reinsurance relates.

Latent Claims

Claims that result from perils that the insurer is unaware of at the time of writing a policy.

Probable Maximum Loss

Estimated largest loss expected to arise from a single event in respect of an insured property.

Criteria for Insurable Risk

Criteria for a risk to be insurable:

- Interest in the risk being insured
- Risk must be financial and of quantifiable nature
- Claim amount having relationship with financial loss incurred
- Risk events to be independent of each other
- Probability of event occurring is very small
- Large number of similar risks to be pooled to reduce variance
- There must be overall limit on risk taken
- Moral hazards to be eliminated as much as possible
- Need of sufficient data to price risks

Policy Document

This sets out terms and conditions under which insurer is liable to pay claims. Items might include details of cover, excess, exclusions, details of premiums, etc.

Exclusion

Exclusions are clauses that limit the circumstances in which a claim may be made. Examples include losses caused by terrorism, depreciation to motor vehicle, etc.

Claim Characteristics

This refers to ways in which and speed with which claims originate, are notified, settled, paid and reopened. They are defined by frequency, severity claims inflation, delay pattern, accumulation of risk and fraudulent claims.

Rating Factors

Risk factor is any characteristic or measure that has influence on the likelihood or severity of a claim. Rating factors are the proxies of risk factors used in pricing.

Exposure Measure

Measures that are used to quantify the level of risk underlying an insurance coverage. Examples include sum insured, vehicle-years, etc.

Capital Requirements

The amount of capital held is subject to minimum requirements if a company is to be allowed to continue to trade.

Lines of Business

There are four main types of GI Covers under which products are sub categorized. They are:

- Liability Insurance
- Property Insurance
- Financial Loss Insurance
- Fixed Benefits Insurance

Employer's Liability

This indemnifies the insured against legal liability for employee injury, disease, or death due to negligence during employment. Basis of cover is **loss-occurring basis**. Exposure measure used is **payroll**. Rating factors used are **type of occupation, workforce location, claims experience, site visitors and materials handled**.

Motor Third Party

This covers the insured's liability for third-party injury or property damage caused by their vehicle. Basis of cover is **loss-occurring** basis. Exposure measure used is **vehicle-year**. Rating factors used are **driver experience, vehicle make/model, safety features, and location**.

Marine and Aviation Liability	This covers the insured's liability for third-party injury, death, or property damage arising from operating a vessel or aircraft. Basis of cover is **loss-occurring** basis. Exposure measure used are **passenger kilometers**, voyages, or in-service capacity. Rating factors used are loss experience, craft type, operating region, usage, and commercial category.
Public Liability	This indemnifies insured against liability for third-party injury or property damage not covered by other liability insurance. Basis of cover is **loss-occurring or claims-made** basis. Exposure measure is **turnover**. Rating factors used **depend on the policy** type and coverages offered.
Product Liability	This covers the insured's liability for third-party injury or property damage due to product faults. Basis of cover is **claims-made** basis. Exposure measure used is **turnover**. Rating factors include **distribution channel, product type, usage, and sales/manufacturing region**.
Professional Indemnity	This covers the insured's liability for client losses due to negligence in professional services. Basis of cover is **claims-made** basis. Exposure measure used is **turnover**. Key rating factors include **service type, firm size, and professional experience**.
Director's and Officer's Liability	This covers legal liability for wrongful acts committed by directors/officers, such as trading while insolvent or publishing false financial statements. It operates on a **claims-made** basis, with **turnover** as the exposure measure. Key rating factors include **company nature and directors' experience**.
Pollution Liability	This covers liability for unintentional pollution. It operates on a **claims-made** basis, with exposure depending on industry type. Key rating factors include **business processes, potential accident impact, and cleanup costs**.
Residential/Commercial Buildings	This policy covers damage to residential/commercial property from fire, theft, and other perils, paying for restoration costs minus any deductible. Basis of cover is **loss-occurring** basis. Exposure measure is **sum insured-years**. Key factors include **sum insured, location, property use, and building age**.
Moveable Property	This policy covers loss or damage to household contents due to fire, theft, or other perils, often as an extension of home insurance. Claims may be paid on a replacement value or new-for-old basis. It follows **loss-occurring** basis. Exposure measure is **sum insured-years**. Risk factors are similar to those for residential property insurance.
Motor Property	This policy covers third-party vehicle damage and losses to the insured's own vehicle due to fire, theft, or accidental damage. Basis of cover is **loss-occurring** basis. Exposure measure is **vehicle-years**. Key rating factors include **mileage, traffic density, driver skill, speed, vehicle durability, and theft risk**.
Marine and Aircraft	This policy covers loss or damage to aircraft, ships, or their contents, as defined in the Marine Insurance Act. Basis of cover is **loss-occurring** basis. Exposure measure is **sum-insured**. Key factors include **craft size, type, age, and the nature of the cargo**.
Goods in Transit	This policy covers loss or damage to goods in transit due to theft, damage, or other perils. Basis of cover is **loss-occurring** basis. Exposure measure is **consignment value**. Key factors include **transport mode, goods type, storage, transit duration, and warehouse time**.

Construction	This policy covers large construction and engineering projects, including damage, defects, or failure to complete. Basis of cover is **loss-occurring** basis. Exposure measure is **contract value**. Key factors include **project type, duration, contractor, materials, technology, and location**.
Extended Warranty	This policy covers repair or replacement costs for faulty parts beyond the manufacturer's warranty, usually for electronics, furniture, or vehicles. Basis of cover is **loss-occurring** basis. Exposure measure is **appliance-years**. Key factors include item **make/model, manufacturer's warranty length, and policy term**.
Fidelity Guarantee	This policy covers financial losses from employee dishonesty, such as fraud or embezzlement. It follows a **loss-occurring** basis, with exposure measured as the loan amount exceeding a set percentage of the property value.
Credit Insurance	This policy covers losses when debtors fail to meet their financial obligations. It includes trade credit and mortgage indemnity insurance. Basis of cover is **loss-occurring** basis. Exposure measure is the **loan amount** exceeding a set percentage of the property's value.
Creditor Insurance	This policy covers individuals who are unable to meet financial obligations due to disability or unemployment. Basis of cover is **loss-occurring** basis. Exposure measure is **loan amount**. Covered risks typically include accidents, disabilities, or job loss leading to income loss.
Business Interruption Cover	This policy compensates businesses for financial losses incurred due to their inability to operate, typically caused by fire at their premises or nearby properties. It operates on a **loss-occurring** basis, with **turnover** as the measure of exposure.
Legal Expense Cover	This insurance covers the insured for legal expenses arising from legal proceedings against them. Basis of cover is either a **loss-occurring or claims-made basis**. Measure of exposure is **policyholder-years**.
Personal Accident	This insurance pays fixed benefits if the insured (or their family) suffers accidental death or a specified injury, such as losing a limb. It operates on a **loss-occurring** basis, with **sum insured** as the measure of exposure. Key rating factors include **age, gender, and hazardous hobbies.**

REINSURANCE PRODUCTS

Retrocession	Reinsurance of reinsurance
Inward Reinsurance	Reinsurance business accepted or written by a reinsurer
Outward Reinsurance	Reinsurance business ceded by an insurer
Participants in Reinsurance Markets	Participants in reinsurance market include: 1. brokers 2. direct reinsurance placements 3. fronting 4. captives
Fronting	Fronting occurs when an insurer, acting as a mere conduit, underwrites a risk and cedes all (or nearly all) of the risk to another insurer which is technically acting as a reinsurer.
Captives	An entity set up with the primary purpose of insuring the risks of its parent company or associated group companies.
Reinstatement	The restoration of full cover following a claim

Overriding Commission Additional commission paid by a reinsurer to an insurer ceding proportional business, as a contribution towards expenses and profit.

Profit Commission A commission paid by the reinsurer to the insurer as a reward for underwriting a profitable business.

Reasons for purchasing Reinsurance Common reasons for purchasing reinsurance include:

1. Limitation of exposure to risk or spreading of risk
2. Avoidance of large single losses
3. Smoothing of results
4. Increasing profitability
5. Improving solvency margins
6. Increasing capacity to accept risk
7. Financial assistance to insurers
8. Availability of expertise of reinsurers

Factors affecting Insurer's risk appetite An insurer's risk appetite is influenced by its size, experience in marketplace, available free assets, size of portfolio, and range within which business outcome may be forecast with confidence.

Ways of writing Reinsurance Reinsurance may be written on facultative or treaty basis.

Facultative Reinsurance Reinsurance of a single risk. Each risk on which reinsurance is required is offered separately.

Advantages – flexibility, mitigation of accumulation of risk, and selective coverage

Disadvantages – time consuming, costly, no certainty, unacceptable terms, insurer can not accept business automatically when offered. A facultative reinsurance facility with an obligation placed on the reinsurer to accept is known as facultative-obligatory reinsurance

Treaty Reinsurance Reinsurance of a group of similar risks under one reinsurance arrangement. It overcomes all disadvantages of facultative reinsurance.

Proportional Reinsurance A reinsurance arrangement where the reinsurer and the cedant share claims and premiums proportionally. Types include **Quota Share**, and **Surplus Lines**.

Non-proportional Reinsurance A reinsurance arrangement where the reinsurer and the cedant do not share claims and premiums proportionally. Types include **Excess of Loss** and **Stop Loss Reinsurance**.

Quota Share Reinsurance Insurer and reinsurer share the same proportion of premiums and losses for all risks covered under the treaty. The cedant's loss ratio for the account will be same before and after reinsurance. Reinsurer would experience a similar claim experience as the cedant due to proportional share of claims.

Advantages – spreads risk, improves solvency ratio, easy to administer

Disadvantanges – cedes same proportion of low-variance/high-variance risk, cedes same proportion irrespective of size and passes share of profit.

Surplus Lines Reinsurance Insurer decides the proportion of premiums and losses to be shared individually for each risk, subject to limits defined in the treaty. The insurer and reinsurer would have different claim experience.

Advantages – enables to write large risk, spreads risk, useful when there is wide variation in size of risk, enables insurer to choose which risk to retain

Disadvantages – administration is complicated, not suitable for personal lines and unlimited covers.

Excess of Loss Reinsurance

The reinsurer indemnifies the cedant for the amount above a certain excess/attachment point and up to an upper limit/detachment point. Insurer and reinsurer would have different claims experience. There are three types of XOLs:

- Risk XL
- Aggregate XL
- Catastrophe XL

Advantages – allows to accept large risks, reduce risk of insolvency, stabilizes technical results, makes efficient use of capital.

Disadvantages – harder to price, more complex than proportional covers

Stop Loss Reinsurance

An aggregate excess of loss reinsurance that provides protection based on the total claims, from all perils, arising in a class or classes over a period. The excess point and the upper limit are often expressed as a percentage of the cedant's premium income rather than in monetary terms.

Financial Reinsurance

A form of reinsurance involving less underwriting risk transfer and more investment risk/timing risk transfer from the cedant than in traditional reinsurance

Time & Distance Deals

A financial reinsurance arrangement whereby an insurer pays a single premium in return for a fixed schedule of future payments that match to the estimated liabilities of the insurer's claim outgo

Spread Loss Covers

Spread loss covers are arrangements where the insurer pays either annual or single premiums to the reinsurer to cover certain claims. These premiums, along with an agreed-upon interest, are accumulated in an experience account, which is settled at the conclusion of the multi-year agreement.

Financial Quota Shares

Financial quota share refers to an arrangement where commissions are provided primarily for financing purposes rather than for transferring risk.

Structured Finance

Reinsurers became involved in structured finance through their finite reinsurance business and the increasing need of financial guarantee insurers and investment banks for additional capacity.

Industry Loss Warranties

Provide reinsurance based on total industry losses from an event, rather than individual losses, with recovery triggered by the predefined industry loss threshold.

Run-off Reinsurance

Under such an arrangement, the 'book' is sold to the reinsurer who assumes all remaining premiums and all of the risk.

Adverse Development Cover – A reinsurance arrangement whereby a reinsurer agrees, in return for a premium, to cover the ultimate settled amount of a specified block of business above a certain pre-agreed amount.

Loss Portfolio Transfer – An arrangement where liabilities in respect of a specific book of business of an insurer is passed from one insurance entity to another.

Capital Market Products

Insurers sometimes transfer risk directly to capital markets rather than reinsurers. Few capital market products are:

- Contingent Capital
- Insurance-linked securities
- Credit Securitization

EXTERNAL ENVIRONMENT

Providers of Insurance

The major providers of insurance and reinsurance services are **direct companies, reinsurers and self-insuring groups**.

Distribution of Direct Business

Insurance business may be obtained through:

- Intermediaries like **brokers, agents and banks**
- **Staff** employed by direct insurers
- Direct marketing channel like **internet and telesales**.

Self-Insuring Groups

Self-insuring groups include captives, pools and P&I Clubs.

Captives

An entity set up with the primary purpose of insuring the risks of its parent company or associated group companies. Reasons for setting a captive:

- Provide cover not available in traditional insurance market
- Control overall insurance expenses of large companies
- Enables corporate to buy cover for risk from reinsurers
- Ensures effective risk management
- Gain tax, legislative and regulatory advantages

Pools

An arrangement where parties collectively share premiums and losses for certain types of specific insurance coverages.

Protection & Indemnity Clubs (P& I)

An association of ship owners to mutually cover certain types of marine risks.

The London Market

The international face-to-face insurance and reinsurance market based in the City of London. Participants in London Market include Lloyd's syndicates, subsidiaries of overseas (re)insurers, small reinsurance companies, self-insuring groups, companies owned by group of insurance and reinsurance companies.

Lloyds of London

Began in Edward Lloyd's coffee shop. Key participants include Names, Syndicates, Managing agents, Members agents, ILVs, and Lloyds brokers.

Names (Lloyds)

Members of Lloyds who provide capital to underwrite risks. Names may be individuals or corporates.

Syndicates (Lloyds)

A group of Lloyd's Names who co-insure risks

Integrated Lloyds Vehicle (ILV)

Syndicates where the full participation is owned by insurance group companies

Lloyds Deposit

A deposit made by Lloyd's members with the Committee of Lloyds before they underwrite any risk

Lloyds Managing Agent

An entity responsible for managing a Lloyd's syndicate. They would provide underwriting, technical, and administrative services.

Lloyds Member Agent

An entity that represents the interests of a Lloyd's Names. They take the responsibility to introduce Names to various syndicates.

Subscription system of Lloyds

Business in London Market is written through subscription or slip system. The slip system is a mechanism used in the Lloyd's market where brokers prepare a "slip" that outlines the details of an insurance or reinsurance risk. This slip is then presented to underwriters in the Lloyd's market, who review the risk and indicate the proportion of the risk they are willing to accept.

Funded Accounting

A method of accounting where all claims, premiums and expenses are allocated to the underwriting year in which the policy incepts.

One-Year Accounting

A method of accounting where all claims, premiums and expenses are allocated to the accounting period, irrespective of when the policy incepts

Three-Year Accounting

A method of funded accounting where underwriting profits are only recognized after the end of third accounting year from the start of the underwriting year

Reinsurance to Close (RITC)

An agreement for transfer of all outstanding liabilities of an underwriting year to a reinsuring party

Professional Standards

Actuaries should keep in mind all relevant professional and technical actuarial standards while determining a rate for an insurance coverage. These are issued by the IFoA and updated from time to time.

Underwriting Cycle

A cycle of high and low insurance prices over a period of few years

Soft Rates

Stage of an underwriting cycle when premiums and hence profitability is high for the insurers in the market

Hard Rates

Stage of an underwriting cycle when premiums and hence profitability is low for the insurers in the market

Regulations in General Insurance

Regulations in General Insurance include:

1. Conduction of external audit
2. Restriction on type of business
3. Limit on premium rate to be charged
4. Restriction on using certain type of information
5. Requirement to deposit assets to back claims
6. Demonstration of solvency on regular basis
7. Prescribed method to find premiums or reserves
8. Restriction on key role holders
9. License for agents selling insurance
10. Pay levy to consumer protection bodies
11. Protection of policyholders in case insurer fails to honour promises

Reasons for Underwriting Cycle

Underwriting cycle exists because:

- Low barriers to entry
- Delay until profitability of insurance business is known
- Simplistic capital requirements
- Economies of scale

Economic Factors affecting Business Environment

Economic factors include those that affect insurance business due to changes in the economy. Inflation, GDP growth, recession, expense inflation, etc. affect the insurance market.

Claims Inflation

Claims inflation could be of following types:

- Price inflation
- Wage inflation
- Medical expense inflation
- Social inflation
- Courts awards inflation

Investment Income

Insurers invest premiums to earn income, with long-tailed lines benefiting more. Pricing includes investment loadings, considering asset-liability duration, liquidity, solvency, and economic conditions like interest and inflation rates.

Currency Fluctuation

Currency rate fluctuations affect insurers who write business in more than one currency or in a currency different then their home/domestic currency. Currency rate fluctuations might distort underwriting results.

Legal Factors

Legal factors include compensation awarded by court to the claimants. Claims would be made due to negligence or breach of contract.

Court Awards

Court awards compensation depends on principle of indemnity. For property damage, compensation would be based on cost of the lost materials/things/property accounting for depreciation. For bodily injury, compensation depends on loss of income, medical costs, and compensation for pain and suffering.

Legislative Factors

Changes in legislation would affect insurers and reinsurers. However, legislation takes time to draft and implement giving insurers some time before the legislation comes in effect. Legislation might make certain insurance coverages compulsory. It may have impact on litigation as well

Social Factors – Attitudes of Society

Attitudes of society that may impact insurance business are:

- Drink and driving
- Crime rates
- Attitude of people towards insurance
- Organization encouraging placing of claims
- Staged accidents

Environmental Factors – Weather

Weather factors have impact on frequency and severity of claims. These factors include:

- Seasonality
- Subsidence and Land Heave
- Geography
- Global Warming
- Climate Change

Catastrophes

A catastrophe is a single event that can give rise to large aggregation of claims. Catastrophes can be natural or man-made.

Latent Claims

Latent claims originate form perils that were not known when the policy was written. It could also mean claims that come into notice only after some years of the cause of loss. Examples of these are asbestos, agent orange, benzene, radiation from mobiles, guns, nanotechnology, etc.

Technological Factors

Changes in the technological space have helped insurers and reinsurers in all areas of their functioning, which lead to increasing efficiencies in insurance operations.

RISK & UNCERTAINTY

Types of Uncertainty

Important types of uncertainties faced by general insurance company are:

- Process Uncertainty
- Parameter Uncertainty
- Data Uncertainty
- Model Uncertainty
- Adjustment Factor Uncertainty
- Market Conditions Uncertainty

Process Uncertainty

The risk inherent in writing business, settling claims and other general operations in general insurance. Process uncertainty can have effect on the cost of claims as well as the other functions of an insurance company. Process uncertainty stems from external as well as internal sources.

External Sources of Process Uncertainty

The external sources of process uncertainty include:

- Inherent Uncertainty individual claims
- Changes in development pattern
- Demand surge
- Climate Change
- Third Party Behavior
- Legislative Changes
- Economic Conditions

Internal Sources of Process Uncertainty

The internal sources of process uncertainty include:

- Changes in business mix
- New Markets
- New Distribution Channels
- Changes in claims handling process
- Profit Sharing Arrangements

Effect of Process Uncertainty on other functions of business

Process Uncertainty would impact not just claims but other areas of business as well. Few examples are as follows:

- Aggregators
- Off-shoring
- Investments
- Competition
- Insurance Cycle
- Expense Uncertainty

Parameter Uncertainty

The risk that an inappropriate parameter has been used in the model. Parameter uncertainty stems from:

- Uncertainty from data used
- Uncertainty from format of data
- Exceptional claims
- Changes in reserving philosophy
- Claims inflation
- New distribution channels

Model Uncertainty

The risk of using a model that is not appropriate for the purpose. Model uncertainty stems from

- Model error
- Programming error
- Incorrect distributional assumptions

DATA USED IN PRICING

Sources of Data

The data used for pricing can come from two main sources:
Internal Sources own historical data of premiums and claims

External Sources data from industry wide sources

Industry-wide Data Collection Schemes

Industry-wide collection schemes collect data from their member offices and then make summaries of this data available to all their members.

Merits: Advantages of industry-wide data collection schemes are:

1. Helps compare insurer's experience with that of industry
2. Helps to understand competitor's business
3. Benchmark development factors may be obtained for reserving

Demerits: Advantages of industry-wide data collection schemes:

1. Potential for distortion owing to heterogeneity
2. Data less flexible than internal data
3. Data might be out of date
4. Not all companies contribute to the scheme
5. Quality of data depends on quality of data supplied by members
6. Data provided by companies may not be comparable because of differences in geographies, policies sold, practices, data stored.

Factors affecting Quality and Quantity of Data

The availability of quantity and quality of data varies:

- within organizations
- between organizations
- between different classes of business

Variation within Organization

Quality of data varies within organization due to different distribution channels. Insurers write business through brokers, agents or directly with customers. This affects quantity and quality of data.

Variation between Organizations

Following factors affect the quality of data between organizations:

- Size and age of the company
- Legacy systems
- Integrity of systems
- Management & Staff
- Nature of organization

Variation by Line of Business

Following factors affect the quality of data between lines of business:

- Claim frequency
- Length of tails
- Underwriting

Uses and Users of Data

The uses and users of data may be summarized as below:

Uses (Functions)	**Users (Professionals involved)**
Administration	Management, Claims Adjusters
Accounting	Accountant
Statutory Returns	Actuary, Management
Investments	Investment Professionals
Management Information	Senior Management
Risk Management	Risk Team, Actuary, Reinsurance
Pricing	Underwriters, Actuary
Reserving	Claims Adjusters, Actuary
Capital Modelling	Actuary
Marketing	Marketing Staff
Experience Statistics	Actuary, CAT team

Information Systems

An insurer/reinsurer would be required to develop robust information systems in order to gather, input, store and manage data effectively.

Proposal Form

Proposal form provides information regarding the policyholder and is a prime information source. Common items on proposal form include details of the insured, estimated sum insured, risk factors based on the class of business, excess or deductibles, etc. Questions on this form should also be unambiguous, designed well and adequate.

Claims Form

Claim form will be the main source of information for claim related details regarding a policy.

Features of Premium Information

Important features of premium that should be recorded are:

- Written and signed amounts
- Payment dates
- Premium adjustments
- Commissions & Discounts
- Cross-selling

Features of Claim Information

Important features of claim information that must be recorded are:

- Definition of claims
- Estimated outstanding amounts
- Multiple claim payments
- Reopened claims
- Claims handling expenses
- Riensurance recoveries
- Class-level adjustments

Policy Data required for Pricing

For **direct insurance & facultative reinsurance**, we need the following data:

1. Dates on cover
2. Policy limits
3. Excess
4. Company's share of total risk
5. Rating factors
6. Details of premium charged
7. Type of coverage
8. Exclusions
9. Policy number linked to claims information

For **treaty reinsurance**, we would also need the following information:

1. Type of reinsurance
2. Basis of cover
3. Treaty limits
4. Aggregate limits and Excess points
5. Reinstatement premiums
6. Treaty terms
7. Reinsurer's share of loss or limit

Claims Data required for Pricing

Claims data required for pricing includes:

- Date of claim event
- Status of claim
- Date closed
- Date reported
- Date, amount of claims payments
- Payment type
- Outstanding claim payments
- Currency of claim payments
- Rating factor details
- Type of claim
- Type of peril
- Policy number to link with policy information
- Unique claim identifier

Sources of Data Error

Few potential sources of data error are:

- Wrong claim number
- Wrong policy number
- Wrong risk details
- Wrong claim date
- Wrong payment dates
- Wrong claim type

Sources of Data Distortion

Few potential sources of data distortion are:

- Changes in claim handling procedure
- Case estimates
- Processing delays
- Large claims
- Return premiums
- Claims inflation

Prevention of Errors

Few measures to ensure prevention of errors are:

1. Data inputs should be checked and screened
2. Ensure consistency in practices over time to minimize errors
3. Digits entered should be checked
4. Minimum and maximum values to be checked
5. Train staff and employees before they handle data systems

Effect of Inadequate Data on Pricing

The impact of inadequate data on pricing include:

1. Wrong premium rate being charged
2. Errors in apparent risk in force
3. Errors in apparent claims experience
4. True distributions of business between different risk groups distort
5. Underwriting losses if rates are too low
6. Decrease in market share is rates too high
7. Adverse selection risks

Pricing with Limited Data

When data is limited, following methods could be used:

1. Use of other data
2. Margins
3. Use of ILFs
4. Qualitative data

ACTUARIAL INVESTIGATIONS

Premium Rate Analyses

In order to analyse the premium rates, we follow the steps as below:

1. Project ultimate claim costs using projection techniques
2. Compare actual vs expected claims, adjusting for abnormalities
3. Project future experience. Factor in uncertainties and future trend assumptions
4. Evaluate the rating structure. Use one-way, two-way, or multivariate rating models
5. Compare final rates with external market data
6. Modify rates based on long-term customer value
7. Reassess past profitability using updated premium rates

Expense Analysis

Expense analysis is important for following reasons:

- Helps allocate expenses correctly between different groups
- Provide useful insights into insurer's financial plans
- Provide information to management
- Provides information to be shown in statutory returns

We divide expenses into **Direct v/s Indirect Expenses** and **Fixed v/s Variable** Expenses. After this, expenses must be split in homogeneous cells.

Direct Expenses

Expenses that can be allocated to specific policies, whether new business acquisition or administration of business already written.

Indirect Expenses

Expenses that relate to general management and service departments

Fixed Expenses

Expenses that do not vary with amount or volume of business written

Variable Expenses

Expenses that vary with the volume of business written

Types of expenses

Expenses other than commission can be split into:

- Initial Expenses
- Administration Expenses
- Renewal Expenses
- Claims Expenses
- Investment Expenses

Treatment of Certain Expenses

It is difficult to split certain expenses into required cells because it is not easy to identify which cell they belong to. Hence, approximate methods are used to get the split. Examples of how few expenses could be split are given below:

Salaries – Salaries are fixed in the short run but variable long-term, allocated directly for single-cell employees, split via timesheets for multi-cell employees, and classified as direct or indirect for admin staff.

Property Costs – Charge actual/notional rent, allocate based on floor space and salary proportions.

Computer Costs – Distribute expenses based on departmental computer usage.

Investment Costs – Deduct investment expenses from expected return

Capital Costs – Amortize one-off costs over product life.

Claims Handling Costs – Allocate direct costs to specific cells; distribute indirect costs by claim volume.

Reasons for Monitoring Business

The main reasons for monitoring business are:

- Assessing performance
- Risk management
- Market intelligence
- Regulatory requirements
- Influencing the market
- Reserving
- Actuarial Control Cycle

Factors to be Monitored

An insurer needs to monitor the following factors:

1. Premium rate changes
2. Portfolio Movements
3. Volumes of Quotation
4. Persistency & Profitability by Source

Portfolio Movements

Portfolio movements refer to changes in underlying risks of the business written. It is important to monitor movements to manage volume and mix of business, manage cross subsidy, and manage the growth of business. Portfolio movements can be in terms of:

- Lapses or renewals
- New volumes
- Strike Rates
- Cancellations
- Endorsements
- Mix of business

Premium Rate Changes

Premium rate change could be defined as:

$$\textbf{Rate Change}_{t_1 \to t_2} = \frac{\textbf{Premium Rate}_{t_2}}{\textbf{Premium Rate}_{t_1}} - 1$$

Methods to calculate premium rate changes are:

- Direct calculation
- Price of a standard risk
- Underwriter's view of rate change
- Rate change at renewal - the formula for this:

$$\textbf{Rate Change}_{t_1 \to t_2} = \frac{\sum \textbf{Premium}_{t_2}}{\sum \textbf{As-if Premium}_{t_1}} - 1$$

where

$$\textbf{As-if Premium}_{t_1} = \textbf{Premium}_{t_1} \times \frac{\textbf{ILF@Lim}_{t_2} - \textbf{ILF@Attach}_{t_2}}{\textbf{ILF@Lim}_{t_1} - \textbf{ILF@Attach}_{t_1}} \times \frac{\textbf{Share}_{t_2}}{\textbf{Share}_{t_1}} \times \frac{\textbf{Exp}_{t_2}}{\textbf{Exp}_{t_1}}$$

Lapses/Renewals

Lapse rate is the ratio of number of policies lapsed to the total number of policies invited for renewal. Renewal rate is the complement of this.

New Volumes

New business rate can be measured in similar way as lapse rate. Instead of using an exposure measure in denominator, we use the same number of policies invited for renewals.

Strike Rates

The ratio of number of written policies to number of quoted policies in a given period. Also called conversion rate.

Cancellation Rate

The ratio of cancelled policies to the number of policies invited for renewal in a particular period.

Endorsements

Endorsements are changes made to a policy due to changes in the underlying risk. Endorsement rate is defined as the ratio of no. of endorsements during a period to no. of policies exposed for the same period.

Mix of Business

Change in mix of business may result in change of profitability levels.

Volume of Quotation

An insurer would track the changes in number of quoted policies over time. This would help to assess the success of marketing campaigns.

Persistency and Profitability by Source

Insurers would measure profitability by branch, broker and direct business. This helps to understand which source provides better quality and long-lasting business.

Use of Actuarial Investigations

The results of actuarial investigations are used for:

1. Carrying profit testing exercise
2. Estimating price elasticity curves
3. Creating lifetime pricing models
4. Redesigning rating tariffs
5. Deciding reinsurance needs
6. Feeding in other process like capital modelling

Features of systems to monitor Business

Desirable features of a system for monitoring business include:

1. Output must be **concise** and tailored
2. Data must be **reliable** and validated
3. Calculations must be **valid**
4. Results must be **validated**
5. Data must be **easy to collect**
6. Calculations must **not be complex**
7. Systems must be **documented** and low maintenance
8. Results must be **clear** and easy to interpret
9. Output must be **consistent over time**
10. Inputs must be **consistent with other data sources**
11. Outputs must be **consistent with other analyses**
12. There must be **minimum delay** between data cut-off date and production of results.

RISK MODELS

Individual Risk Models

Individual Risk Model considers a fixed number of risks in a portfolio. **Assumptions** of this model are:

1. Risks are independent
2. Claim amounts are not necessarily identically distributed
3. Number of risks do not change over time
4. There can not be more than one claim for each risk

Collective Risk Models

Assumptions of this model are:

1. Claim amounts X_i are independent and identically distributed
2. Claim amounts X_i and random variable for claim number N are independent of each other

Total claim amount, S, payable during a specified period is given by:

$$S = X_1 + X_2 + X_3 + ... + X_N$$

where X_i is claim amount in respect of ith claim and N (random variable) is number of claims during the period.

Mean of S:

$$E(S) = E(X)E(N)$$

Variance of S:

$$\text{Var}(S) = E(N)\text{Var}(X) + [E(X)]^2\text{Var}(N)$$

MGF of S:

$$M_S(t) = M_N[\log M_X(t)]$$

Recursive formula for G(x)

The recursive formula for the probability of r number of claims, i.e., $P[N = r]$ is given by:

$$P[N = r] = p_r = \left(a + \frac{b}{r}\right) p_{r-1} \text{ for } r = 1, 2, 3, ..$$

The recursive formula for the probability of r aggregate claim amount, i.e., $P[S = r]$ is given by:

$$P[S = r] = g_r = \sum_{j=1}^{r} \left(a + \frac{bj}{r}\right) f_j g_{r-j} \text{ for } r = 1, 2, 3, ..$$

where:

- a & b are constants that depend on the claim frequency distribution N; and
- $f_j = P[X_i = j]$
- $g_0 = p_0$

Normal Approximation to G(x)

When $E(N)$ is large, we may assume that S follows a Normal Distribution with mean μ and variance σ^2. Therefore,

$$G(x) = P[X \leq x] = P\left[\frac{S - \mu}{\sigma} \leq \frac{x - \mu}{\sigma}\right] \approx \Phi\left(\frac{x - \mu}{\sigma}\right)$$

We may estimate μ and σ as:

$$\mu = E[S] = E[N]E[X],$$
$$\sigma^2 = E[N]\text{Var}[X] + [E(X)]^2\text{Var}[N].$$

Translated Gamma Approximation to G(x)

We equate means, variances and coefficient of skewness of S and $k + Y$, we get:

$$\mu = k + \frac{\alpha}{\delta},$$
$$\sigma^2 = \frac{\alpha}{\delta^2},$$
$$\beta = \frac{2}{\sqrt{\alpha}}.$$

From the above three equations, we estimate k,α and δ from the known values of μ,σ^2 and β which are mean, variance and coefficient of skewness of S.

Stochastic Simulation

Stochastic simulations may be used to approximate a distribution for aggregate claims, i.e., G(x). This requires to simulate number of claims.

RATING METHODOLOGIES

Categories of Pricing

The General Insurance Premium Rating Issues Working Party (GRIP) has outlined five categories of pricing:

- **Tariff** - Regulators influencing premium rates
- **Qualitative** - Rates based on subjective factors
- **Cost plus** - Rates based on statistical methods
- **Distribution** - Rates based on non-cost elements
- **Industrial** - Rates based on operational efficiency

Components of Pricing

The "technical premium" has the following components:

Risk Premium – consists of pure risk rate and loading for CAT and large loss

Office Premium – cost of reinsurance, expenses, cost of capital, investment income

Other Considerations – rating factors, practical considerations

Pure Risk Premium

Pure risk premium may be estimated using following steps:

1. collection of relevant data
2. adjusting and grouping of data
3. selection of appropriate rating model
4. analysing the data
5. setting assumptions required by the model
6. testing the assumptions for goodness of fit
7. running the model to arrive at an estimate of cost of claim
8. performing sensitivity and scenario testing

Homogeneity of Data

Data needs to be grouped into homogeneous cells where risks in each cell represent similar characteristic. Reasons for grouping data include:

- avoiding unintentional cross-subsidies
- profitability will not depend on cross section of risks
- gain market acceptance when launching particular risk division

Trending Data

Past data is subject to change over time due to various reasons. Past data needs to be trended for:

- Unusual base experience
- Trends in claim experience
- Inflation
- Changes in mix of risks
- Changes in distribution meth
- Changes in coverage
- Changes in claim settlement procedure
- Changes in underwriting
- Changes in perils covered
- Changes in self-retention limits
- Changes in legislative factors
- Advancement in tech
- Medical advances
- Changes in construction of property

Projecting Claims & Exposure

To arrive at risk premium, we divide projected claims by projected exposure values.

Projecting Claims – For projecting claims, we first project claims with adjustments and trends. Then claims need to be projected to ultimate.

Projecting Exposure – When exposure units are measured in monetary terms, base exposure values should be projected using an appropriate inflation rate, which may differ from the rate applied to claim costs. This projection should only extend to the midpoint of the exposure period for the new rates.

Catastrophe and Large Claims Loading

When analysing claims, we separate attritional claims from large and catastrophe claims. For catastrophe losses, we estimate their cost from a proprietary catastrophe model. For non-catastrophe large losses, cost can be estimated based on:

- omitting them from the analysis and allowing separately in risk premium
- truncate large loss to a certain point and spread any cost above this level across large portfolio of risks
- leave large loss in claims data and conduct analysis

Office Premium

Office premium is the risk premium adjusted for cost of reinsurance, expenses, profit loading, and investment income.

Cost of Reinsurance

Reinsurance premium can be incorporated in two ways:

1. as net cost of reinsurance based on gross risk premium
2. as gross cost of reinsurance based on net risk premium

Expense Loading

Commissions, expenses and other margins may be incorporated by either **adding an overall percentage** or **splitting fixed and variable expenses**.

Profit Loading

In order to give a reasonable return to shareholders or capital providers, profit loading would also be added to premium rates.

Investment Income

Investment income is expected to be earned on the premium received by the insurer. This would also be allowed for in the premium rate. This can be done by discounting cost of claims and expenses at a suitable rate of interest to the date when premium is paid.

Other Considerations in Rating

After arriving at office premium, we consider the rating factors and practical considerations.

Rating Factors

The rigor of underwriting depends on class of business. For **personal lines**, underwriting is completely based on the rating factors. For **commercial lines**, like commercial fire, underwriting is a skill job based on reports.

Conditions of Good Rating Factors

A good rating factor should satisfy the following conditions:

- defines the risk clearly
- does not correlate too closely with other factors
- are practical to obtain and record
- are objective
- are factual and verifiable
- are acceptable to policyholder
- are based on current factors used in the market

Selection of Rating Factors

To select rating factors, we perform ANOVA exercise. This includes:

One-way analysis – amount of variability explained by each factor

Two-way analysis – each factor is investigated along with correlation with others

Multivariate analysis – This is an extension of the two-way analysis which allows for all factors and correlations.

Practical Considerations

The actual premium charged may be different from the theoretical office premium due to following factors:

- Business Objectives
- Competitive Pressures
- Difficulty in establishing price
- Insurance cycle
- Market acceptability
- Renewal process
- Use of no-claims discounts
- Profit optimization

Other Influences on Pricing

Other influences include:

- Competition and the need to maintain or build market share
- Availability of capital to support new business
- Impact of reinsurance capacity
- Sophistication of sales and quotes system
- Demand of regulators
- Relationship with brokers and distributors
- Differences between "direct" approach and traditional routes

FREQUENCY-SEVERITY & BURNING COST RATING

From the Ground Up (FGU)

A statement that details insurer's claim experience is said to be "from the ground up" when it includes the number and distribution of all claims, irrespective of the size.

Aggregate Deductible

The maximum amount that the insurer is responsible for paying when all losses are combined.

Non-Ranking Deductible

The portion of deductible applied to each individual loss that does not contribute to insurer's aggregate deductible.

Ranking Deductible

The portion of deductible applied to each individual loss that contributes to the insurer's aggregate deductible.

Trailing Deductible

The amount that insured retains for each individual loss after the aggregate deductible has been completely exhausted.

Per Occurrence Limit

The maximum amount that the insurer would retain for each loss

Annual Aggregate Limit

The maximum amount the insurer will cover for all losses arising during a one-year policy period.

Frequency-Severity Approach

This method estimates claim frequency and severities separately and then combines them to estimate the expected cost of claims.

Advantages – mirrors the underlying process, complex structures may be priced, helps identify trends, additional insights into loss amounts.

Disadvantages – data requirements are onerous, time-consuming process, requires high level of expertise.

Data Requirements for F-S Approach

There could be issues in data with regards to form, consistency and choice of base period. In addition to data requirements discussed in Chapter 6, following data would be needed:

1. Submission Documents
2. Exposure Information
3. Individual Claim Information

Trending for F-S Approach

Trends need to be applied separately for frequency and severity under F-S method. While trending, we must:

- Project historical frequency and severity in line with trends assumed to current values; and
- Project them to the mid-point of future exposure period

Frequency Trends

Causes of frequency trends include changes in:

- Accident frequency
- Propensity to make claims due to social inflation
- Legislation
- Structure of risk

Frequency is calculated as:

$$\textbf{Frequency} = \frac{\textbf{Ultimate number of losses}}{\textbf{Exposure measure}}$$

Severity Trends

Causes of severity trends include:

- Economic inflation
- Economic conditions
- Changes in court awards
- Changes to structure of risk

Severity is calculated as:

$$\textbf{Severity} = \frac{\textbf{Ultimate cost of loss}}{\textbf{Ultimate number of losses}}$$

Developing Losses in F-S Approach

After adjusting individual losses for trends, it is important to project them to their ultimate levels since past claims may not be fully developed. Methods that may be used to develop losses include:

1. Applying an incurred development factor to each individual loss
2. Developing only open claims using "case estimate" claims ratio
3. Estimating IBNR based on known losses from a cohort of claims
4. Using stochastic development methods to consider variation in individual ultimate loss amounts

Fitting Distributions in F-S Approach

After adjusting the historical data for trends, and developing individual losses, we fit frequency and severity distributions. The stages involved in fitting the distributions are:

Stage I: Choice of base period – Older policy years give reliable but less relevant estimates, so we may exclude recent years, exclude underdeveloped years, or weight developed years more.

Stage II: Choice of distribution – Common distribution used for claim severity are Log-Normal, Weibull, Pareto, Gamma, Generalized Pareto. Distributions used for claim frequency are Poisson and Negative Binomial.

Stage III: Parameter estimation – Parameter may be estimated using method of moments, least square estimates or maximum likelihood estimates

Stage IV: Testing Fit – The fit must be checked using statistical methods.

K-S GoF and A-D GoF tests

Kolmogorov-Smirnov GoF – This test checks if a given sample comes from a specified distribution by comparing the empirical distribution of the sample to expected cumulative distribution.

Anderson-Darling GoF – This test is similar to K-S GoF, where the test statistics measures the difference between empirical distribution of the sample and CDF of assumed distribution. However, the A-D GoF test places more weight on differences in tails of the distribution. The A-D GoF test is more sensitive to deviations in the tails and more powerful than K-S GoF.

Burning Cost Approach

Burning cost is the cost of claims expressed as an annual rate per unit of exposure.

Advantages – simple, less data onerous, quicker, experience of individual risk or portfolio of risk can be allowed for

Disadvantages – difficult to spot trends, making adjustments is difficult, crude approach.

Data Requirements for Burning Cost Approach

In addition to data requirements discussed in Chapter 6, policy data and estimated outstanding claim amounts need to be known.

Burning Cost Premium

Premium is given by:

$$\textbf{Burning Cost Premium} = \frac{\sum \textbf{Claims}}{\textbf{Total Exposure}}$$

Trending in Burning Cost Approach

Exposure and claim amounts need to be projected to current levels. Different approaches may be used to trend past data.

Developing Losses in Burning Cost Approach

Without individual loss data, assumptions will be less detailed than in the frequency-severity method. IBNR factors are typically derived from individual risk data or aggregated business results, with adjustments for inflation and insights from recent reserving exercises if relevant.

RATING USING ORIGINAL LOSS CURVES

Introduction

Original Loss Curves are used in general insurance to price layers at which data is too sparse to derive a premium rate.

Types of Curves

The most used forms of original loss curves are:

Exposure Curves – These curves represent the proportion of total premium allocated to different primary coverage limits, or deductibles.

Excess of Loss Scales – They are like exposure curves; except they give proportion of premium to be allocated to excess layers rather than primary layers.

Increased Limit Factors – They are a table of multiplicative factors giving ratio of premium for higher limits to basic limit premium.

Properties of Original Loss Curves

If:

- X is a random variable representing severity
- $F_X(x)$ is CDF of X
- $S_X(x) = 1 - F_X(x)$
- $LEV_X(x)$ is the Limited Expected Value distribution of X

We have,

$$LEV'_X(x) = S_X(x)$$

Hence, the properties of loss curves are:

- $LEV(x)$ is an increasing function
- It increases at a decreasing rate since $S(x)$ is non-increasing

Property Business - Use of Exposure Curves

They are defined as:

$$G(x) = \frac{LEV_Y(x)}{E[Y]}$$

where Y is a random variable that represents size of loss (X) as a proportion to measure of risk (M). Hence, $Y = \frac{X}{M}$. $G(x)$ is a curve that represents the ratio of total claims cost up to a specific point x to the overall claims cost, where x is selected proportion of maximum claim. Steepness of $G(x)$ would depend on the severity of underlying loss distribution. Exposure curves may be used to price property XL treaty having a structure L excess of D, using following formula:

$$C_L = C \times \left(G\left(\frac{L+D}{M}\right) - G\left(\frac{D}{M}\right)\right)$$

where

- C_L is the claim cost to the layer priced
- C is the ground-up loss cost

Relative Loss Distribution

The relative loss size distribution is given by random variable $Y = \frac{X}{M}$. An important assumption underlying exposure curves is that Y is independent of size of risk. However, this assumption holds true only when data is homogeneous.

Steps in Property XL using Exposure Curves

Steps involved in pricing a property excess of loss treaty include:

1. Gather original premium and sum insured **data** categorized in bands
2. Estimate a **representative sum insured** for each band
3. Estimate an **original loss ratio**
4. Adjust treaty limits for **inflation and trends**
5. Choose an appropriate **exposure curve** for the line of business
6. Express attachment and detachment points of the **layer as a proportion of sum insured** (Y_1 and Y_2)
7. Determine $G(Y_1)$ and $G(Y_2)$ from **selected exposure curve**
8. Compute **loss cost to layer** using $G(Y_2) - G(Y_1)$
9. Derive **loss rate** as total loss cost to layer divided by total premiums

Considerations in Exposure Curves

Following considerations need to be accounted for:

- Homogeneity of Data
- Claims Inflation
- Choice of Exposure Curve
- Estimation of Original Loss Curve
- Original Deductibles
- Inuring Reinsurance
- Stacked Limits

Deriving Exposure Curves

Steps in deriving exposure curves include:

1. Collect claims data regarding amount paid, risk size, cause of loss
2. Each claim is expressed as percentage of risk size
3. Data to be grouped in homogeneous groups based on perils
4. Construct a table of losses as a percentage of risk (x%). We find total value of losses less than or equal to x% of PML (Let this be B). Then, we calculate first x% of losses greater than x% of PML (Let this be C).
5. Find total accumulated loss costs as sum of B and C.
6. Finally, empirical exposure curve is found as the ratio of (B + C) to B.
7. Combine groups for which there is no significant difference
8. Smoothen the empirical curves

Casualty Business

ILFs are used in casualty rating due to no upper limit on loss amounts.

$$ILF(x) = \frac{LEV_X(x)}{LEV_X(b)}$$

ILFs may be used to price casualty XL treaty having a structure L excess of D, using following formula:

$$C_L = C_b \times (ILF\,(L + D) - ILF\,(D))$$

where:

- C_L is the cost to the layer priced
- C_b is the basic limit loss cost

Steps in Casualty XL using ILFs

We may follow the same steps to price casualty XL treaty as used with exposure curves when pricing property XL, however, with following differences:

- For casualty XL pricing, we estimate loss cost for original limit as a starting point. This is given by:

$$C_I = \text{Original Limit Loss Cost} = C_b \times ILF(I)$$

- The layer loss cost then changes to:

$$C_L = \text{Layer Loss Cost} = C_I \times \left(\frac{ILF(L + D) - ILF(D)}{ILF(I)}\right)$$

Considerations in using ILFs

When using ILFs, following considerations to be made:

1. Treatment of expenses
2. Claims inflation
3. Treaties on cession basis

Deriving ILFs

When deriving ILFs few problems may be faced. These are lack of volume of data, unavailability of information on large loss, losses adjusted for trends, claims might not be closed. ILFs may be derived using methodology devised by ISO in the US.

Empirical Survival Function

The survival function is given by:

$$\hat{S(u_n)} = \prod_{i=1}^{n} C\hat{S}P(i) = \prod_{i=1}^{n} \frac{Nu_i}{NI_i}$$

Curves used in Practice

Some curves used in practice by reinsurers are:

1. Curve fitting
2. Riebesell curves
3. Market curves

Advantages & Disadvantages of Loss Curves

Advantages – Simple to implement, easy to explain, loss cost internally consistent, use with less data available

Disadvantages – Application may be difficult, sensitive to curve chosen, market wide data collection

GENERALIZED LINEAR MODELS

Multiple Linear Regression

A multiple linear regression model with k parameters representing the relationship between response variable Y_i and independent variables X_ik, takes the form:

$$Y_i = \beta_0 + \sum_{j=1}^{k} \beta_j f_j(X_{ij}) + \varepsilon_i$$

where

- β_i is the jth parameter value
- ε_i are error terms

The parameters of the model can be estimated using method of maximum likelihood estimates.

Exponential Family

The exponential family is a set of distributions whose PDF can be written in the form:

$$f(y;\theta,\varphi) = \exp\left(\frac{y\theta - b(\theta)}{a(\varphi)} + c(y,\varphi)\right)$$

where

- $a(\varphi)$,$b(\theta)$ and $c(y,\varphi)$ are specific functions depending on the distribution.
- θ is the canonical and φ is the scale parameter.

The mean and variance of Y are given by:

$$\mu = E[Y] = b'(\theta) = \mu(\theta_i),$$
$$\text{Var}[Y] = a(\varphi)b''(\theta).$$

The variance function is defined as:

$$V[\mu] = b''(\theta)$$

Tweedie Distribution

Pure premium data is challenging to model due to a spike at zero and a wide range of positive values. The Tweedie distribution addresses this by allowing a variance function proportional to ^{p}, accommodating both zero-inflation and claim variability.

Generalised Linear Models

The multiple linear regression generalizes into the following GLM structure:

$$Y_i = g^{-1}\left(\sum_{j=1}^{k} X_{ij}\beta_j + \xi\right) + \varepsilon_i$$

where

- ε_i is the error term
- ξ is an offset or known effects

The important components of a GLM are:

Distribution of response variable – Y_i has distribution from exponential family.

Linear Predictor – Linear predictor, η is a function of co-variates given by:

$$\eta = \sum_{j=1}^{k} X_{ij}\beta_j + \xi$$

Link Function – Connects η with μ. The relationship is:

$$\mu = g^{-1}(\eta)$$

Estimating Parameters of a GLM

If the distribution of response variables is Normal Distribution and the link function used is identity link, the parameters may be estimated using the equation:

$$\beta = (X^T X)^{-1} X^T Y$$

If other distributions are used, other methods are used.

Applications of GLM in Insurance Pricing

GLMs can be used in general insurance pricing to predict the claim frequency, claim size or loss ratios.

Response Variable – could be claim frequency, average claim amount or loss ratios for a class of business.

Independent Variables – could be the rating factors (Categorical and Numerical) that affect cost of claims depending on the class of business.

Interaction Term – An interaction term improves the model by capturing the combined effect of multiple factors, adding predictive value beyond individual factors.

Deviance

Let d be each observation's contribution to the deviance defined by:

$$d(Y_i; \mu_i) = 2\omega_i \int_{i=1}^{Y_i} \frac{Y_i - \zeta}{V(\zeta)} d\zeta$$

The total deviance is therefore defined as:

$$D = \sum_{i=1}^{n} d(Y_i; \mu_i)$$

Scaled deviance is the ratio of deviance to the scale parameter, defined as:

$$D^* = \frac{D}{\varphi}$$

Analysis of Significance of Factors - Statistical

Important statistical tests are:

Chi-Squared Test – Two nested models may be compared using the test:

$$D_1^* - D_2^* \sim \chi^2_{df_1 - df_2}$$

F-Statistics – If scale parameter is not available, this test will test:

$$\frac{D_1 - D_2}{(df_1 - df_2)\frac{D_2}{df_2}} \sim F_{df_1 - df_2, df_2}$$

Akaike Information Criteria – The lower AIC, better the model

Analysis of Significance of Factors - Graphical

Graphical methods used to analyse significance of factors include:

- Hessian Matrix
- Comparison with expectations
- Comparison over time
- Consistency check with other factors

Residuals

Residuals show how the fitted values differ from actual observations.

Deviance Residuals – Deviance residuals is defined as:

$$r_i^D = sign(Y_i - \mu_i)\sqrt{d(Y_i; \mu_i)}$$

Pearson Residuals – Pearson residual is defined as:

$$r_i^p = \frac{Y_i - \mu_i}{\sqrt{\frac{\varphi V(\mu_i)(1-h_{ii})}{\omega_i}}} = \frac{Y_i - E[Y_i]}{SD[Y_i]\sqrt{1-h_{ii}}}$$

where h_{ii} is called the leverage and is the ith diagonal element of the hat matrix:

$$H = X(X^T X)^{-1} X^T$$

The value of Pearson residual ranges from 0 to 1. A value close to 1 means that the observation heavily influences the prediction, make the residual error small.

Residual Plots

The residual patterns of models of average costs, frequency, etc. may be plotted. A good model should produce residuals that:

- are symmetrical about x-axis
- have an average residual of zero
- are fairly constant across the width of fitted values

Cook's Distance

Cook's distance for the ith data point is defined as:

$$c_i^p = \frac{h_{ii}}{(1-h_{ii})(\sum h_{ii})} \times (r_i^p)^2$$

Complete & Marginal Interactions

Interactions may be expressed in two ways:

Complete Interactions – This considers a single factor representing every combination of the two factors.

Marginal Interactions – This considers single factor effects of the two factors and the additional effect of an interaction term over and above the single factor effects.

Aliasing

Aliasing occurs due to linear dependency among the observed independent variables $X_1, X_2, .., X_P$.

Intrinsic Aliasing – This occurs due to inherent dependencies in the definition of covariates. This is commonly observed when categorical covariates are used.

Extrinsic Aliasing – This occurs when covariates are dependent due to data characteristics rather than inherent properties. It happens when one factor is perfectly correlated with another.

Near Aliasing – This occurs when two or more factors contains levels that are almost, but not quite, perfectly correlated.

Parameter Smoothing

Parameter smoothing is the process of adjusting parameter estimates to reduce volatility, prevent overfitting and ensure a more stable model. There are four methods to factor simplification:

- group and summarize data prior to loading
- grouping in modelling package
- curve fitting
- piecewise curve fitting

Offsetting

Offsets are used to fix the relativities of a factor to a set of values that would differ from naturally fitted values. For example, to fit NCD in GLMs.

MULTIVARIATE MODELLING

Information on Proposal Form - Motor Insurance

A motor insurer would seek the following information when preparing a quote:

Information on policy & coverage:

- Type of cover
- Payment frequency
- Voluntary excess

Details of each driver:

- Driver experience
- Driver restrictions
- Age & Relationship

Details of proposer:

- Age & Gender
- Marital Status
- Occupation

Details of vehicle:

- Registration Number
- Make/Model
- Parking Location

Risk Factors – Motor Insurance

Some risk factors used in motor insurance pricing are:

Drivers:

- Driving style, experience, level of skill, powers of observation, risk attitude, ability to predict road hazards

Vehicle:

- Value of vehicle/repair costs if damaged
- Safety features available to protect passengers & theft
- Make, model, speed, size

Environment:

- Geography where the vehicle is used
- Type of road
- Time of the day and pedestrian risk
- Natural hazards

Exposure:

- Amount of driving (miles/minute)

Third Parties:

- Other people in the vicinity of the insured

Information on Proposal Form – Home Insurance

An insurer would seek the following information at point-of-sale:

Policy:

- Date on risk
- Number of adults
- Number of claims
- Type of cover
- Accidental damage cover
- Excess

Proposer:

- Age, gender, marital status
- Smoker/non-smoker
- Employment status

House Details:

- Year of purchase
- Type of property
- Building status
- Construction type
- Postcode
- Ownership
- Contents value
- Flood/subsidence
- Lock types

External Data

Information on Proposer:

- Previous insurer claims experience
- Cross-product holdings
- Customer lifetime value models
- Customer behavior models
- Credit score

Information on Location:

- Socio-economic data of the region
- Soil type data for subsidence
- Flood data, theft survey data
- Census & Valuation data

Information on insured asset:

- Data from insurers trade body, for example ABI in UK
- Data from motor registration authority
- Additional asset data
- Data from inter-industry agreement to share claims and underwriting information, for example, CUE in UK

Proxy Rating Factors

Due to subjective nature of questions on proposal form, we need proxy factors to quantify risk. The effectiveness of such proxy factor depends on

1. The extent to which factor directly **reflects an actual risk**
2. Whether the proxy is **verifiable fact** known to the proposer
3. Whether the factor has a **clear influence on pricing**
4. Degree of **overlap between proxy and other existing risk factors**

Spatial Smoothing

Spatial smoothing helps by adjusting predictions based on neighboring values, reducing noise and improving credibility.

Distance-based Smoothing:

- Considers information nearby location codes based on distance
- More weight to closer location codes and less to farther ones
- Applies regardless of urban/rural status or natural barriers
- Useful for weather related perils
- Simple to implement without any distributional assumptions

Adjacency-based Smoothing:

- Considers information about directly neighboring location codes
- Complex process since each code is influenced by its neighbors
- Incorporates distributional assumptions
- Accounts for natural or artificial boundaries like rivers
- Handles rural and urban differences well

Forms of Model

For different model forms like claim frequency, claim severity, propensity, etc. we use different distributions, link functions, scale parameters, etc. A summary of this is as follows:

Model	Error Distribution	Link Function	Scale Parameter	Variance Function	ω_i
Claim Frequency	Poisson	ln(y)	1	μ	Exposure
Claim Numbers	Poisson	ln(y)	1	μ	1
Claim Severity	Gamma	ln(y)	Estimated	μ^2	Claim Numbers
Total Claims Cost	Tweedie	ln(y)	Estimated	$\mu^{1.5}$	Exposure
Propensity	Binomial	$\ln\left(\frac{y}{1-y}\right)$	1	$\mu(1-\mu)$	1

Initial Analyses

Prior to multivariate modelling, initial analyses are performed. This includes:

- One-way analyses
- Two-way analyses
- Correlation analyses
- Distribution analyses

One-way Analyses

One-way analyses are performed for following reasons:

1. Exposure should be well distributed among each factor level.
2. Help to identify levels in a factor that have low or no exposure.
3. Provide preliminary indication of the impact of particular variable

Two-way Analyses

Two-way analyses key statistics across factor combinations to identify interactions between covariates. This is particularly helpful when there is some correlation between variables.

Correlation Analyses An understanding of correlation between variables is helpful when interpreting the results of a GLM. For categorical factors, Carmer's V statistic is used.

Distribution Analyses Distribution analysis involves examining how response distribution varies across factor levels, detect anomalies like large claims and identify biases in average reserves.

Claim Types Different claim types must be modelled separately because they may be affected by different rating factors in different ways. This also helps in modelling products having different coverages.

Model Combining When modelling, we model frequency severity separately. We also model different claims type separately. However, all of it needs to be combined to find the ultimate cost of claim.

Model Validation Models need to be validated by testing on "out-of-sample" data. Another way to do this exercise is to plot a graph of predicted values and actual values from the out of sample data to analyze the differences.

Lift Curve A lift curve helps assess a model's accuracy by ranking policies (in order of expected experience according to model being tested) based on predicted claims and grouping them into equal bands. The actual claims for each group are then plotted. A steeper curve means the model better separates high and low risks, making it more effective. This also helps compare different models.

Gains Curve Gains curve is also a way to validate a model. In this method, data is ranked from high to low based on predicted values. The chart then compares the cumulative predicted and actual values. The **Gini coefficient** measures the model's lift—it represents the area between the model curve and the diagonal, showing how well the model distinguishes risk levels. Higher the Gini coefficient, the more the predictive model.

Implementing Rates Before the theoretical premium rates from the model are implemented, they need to be compared with **current rates and competitors rates**.

CREDIBILITY THEORY

Credibility Theory Credibility theory can be used to set premium rates by considering both actual experience and external information. The basic formula for credibility-weighted estimate is:

$$\textbf{Estimate} = Z \times (\textbf{Observation}) + (1 - Z) \times (\textbf{Other Information})$$

Classical Credibility Theory This method involves considering the quantity of data needed before we can assign 100% credibility to observed data. This is also known as "**full credibility criterion**." "**Partial Credibility**" is when we have less experience data than is needed for achieving full credibility.

Bayesian Credibility The 'Bayesian' credibility, Z_B, is based on minimizing mean square error, and is given by:

$$Z_B = \frac{n}{n+k}$$

where

$$k = \frac{E[s^2(\theta)]}{\text{var}(m(\theta))}$$

Classical vs Bayesian Credibility

Both methods may produce same results if the full credibility standard for classical credibility n_N is about 7 to 8 times larger than Bayesian credibility factor k. Bayesian credibility never reaches $Z = 1$. Both the models are affective at improving stability and accuracy of estimates.

Standards for Full Credibility

If the objective is to be within a proportion of $\pm k$ of the mean, μ, with the probability of at least P, then for $\Phi(y) = \frac{1+P}{2}$, standards for full credibility are:

Measure	Standards for Full Credibility
Frequency (Poisson)	$n_N \geq \frac{y^2}{k^2}$
Frequency (General)	$n_N \geq \frac{y^2}{k^2}\left(\frac{\sigma_N^2}{\mu_N}\right)$
Severity	$n_X \geq \frac{y^2}{k^2}\left(\frac{\sigma_X}{\mu_X}\right)^2$
Aggregate Losses (Poisson)	$n_S \geq n_N + n_X$
Aggregate Losses (General)	$n_S \geq \left(\frac{y}{k}\right)^2\left(\frac{\sigma_N^2}{\mu_N} + \frac{\sigma_X^2}{\mu_X^2}\right)$

Partial Credibility

Square Root Rule – If n is the expected number of claims for volume of data, and n_N is standard for full credibility. The partial credibility is:

$$Z = \sqrt{\frac{n}{n_N}}$$

Buhlmann-Straub Credibility Model

If:

- V_i = Volume Measure for risk i
- S_i = Insurance claims for risk i
- X_i = claims ratio = $\frac{S_i}{V_i}$ for risk i

The model assumes existence of a latent parameter θ_i such that:

$$E[X_{ik} \mid \theta_i] = \mu(\theta_i),$$
$$\text{Var}[X_{ik} \mid \theta_i] = \frac{\sigma^2(\theta_i)}{V_{ik}}.$$

Benchmark claims ratio is: $\beta = E[\mu(\theta_i)]$
Expected variance of observed claims ratio per unit of V is: $\phi = E[\sigma^2(\theta_i)]$
Variance of long-run claims ratio for all risks is: $\lambda = \text{var}[\mu(\theta_i)]$
The credibility-based claims ratio is: $C = z_i X_i + (1 - z_i)\beta$ where $z_i = \frac{V_i}{V_i + \frac{\phi}{\lambda}}$

Assumptions of Buhlmann-Straub Credibility Model

Following are the assumptions of Buhlmann-Straub credibility model are:

1. V_i and X_i are based on volume measures V_{ik} and claims ratio X_{ik} for risk i across years k
2. ith risk is described by pair, $(\theta_i, (X_{ik})_{k\geq 1})$ where $(X_{ik})_{k\geq 1}$ is sequence of claims ratio observed for risk i
3. Pairs $(\theta_i, (X_{ik})_{k\geq 1})$ are mutually independent
4. θ_i are independent and identically distributed
5. Conditionally on θ_i, X_{ik} are independent

Complement of Credibility

An actuary must consider the following issues when choosing the complement:

- Competitive market issues
- Regulatory issues
- Statistical issues
- Practical issues

Desirable Qualities of Complement of Credibility

The desirable qualities of the complement of credibility are:

- accuracy as predictor of next year mean loss costs
- unbiasedness as predictor if next years mean loss costs
- independence from the base statistic
- availability of data
- ease of computation
- relationship to loss costs

Practical Issues when using Credibility Theory

Issues to consider when using credibility theory are:

1. simplicity
2. visibility – imposing a maximum swing, or self-rating
3. goodness of fit (accuracy v/s simplicity)
4. level of grouping versus accuracy
5. source of data
6. stability of data
7. use of partial premiums
8. choice of complement of credibility
9. judgement when considering how to allow for large claims

REINSURANCE PRICING

Similarity – Direct and Reinsurance Pricing

The underlying principles of deriving the risk premium and office premium is same for reinsurance business as for direct business. The office premium would be estimated after allowing for:

Expenses – A reinsurer would load for its own expenses using same techniques as an insurer.

Profit/ROE – As insurers, reinsurer would also build a profit loading.

Brokerage and Commission – For Quota Shares, reinsurance premiums are higher so the brokerage is lower (in the range of 1%-2%).

Differences – Direct and Reinsurance Pricing

The differences between direct and reinsurance pricing are:

1. volume and data available will be different
2. there are very few standard contracts
3. individual nature of pricing exercise
4. reinsurance pricing may be stochastic
5. pricing depends on whether the reinsurer is required to quote
6. cedant is as knowledgeable as the reinsurer which is not the case between insurer and policyholder in direct insurance
7. exact pricing approach also differs materially by line of business

Proprietary Catastrophe Models

Proprietary CAT models like RMS, AIR and EQECAT are used to price property cat business. When comparing models, it is important to consider

- Different models are better suited for **different perils**
- Different models use **different assumptions**
- **Input data needs** vary by model which influences reliability
- The **output** from different models may differ

Occurrence Exceedance Probability

Probability that largest individual event loss in a year exceeds a particular threshold.

Aggregate Exceedance Probability

Probability that aggregate losses from all risk events in a year exceeds a particular threshold.

Non-Proportional Reinsurance Pricing – Exposure Rating

In exposure rating, reinsurers would rely on **benchmark** to represent the market severity distribution. Suppose an excess of loss reinsurance treaty layer LR xs ER. The 100% limit is L and policy excess is E. Then, the proportion of premium to be allocated to the given layer is given by:

$$\textbf{Proportion} = \frac{ILF(LR+ER) - ILF(ER)}{ILF(L+E) - ILF(E)}$$

The above formula may need adjustments for:

- When reinsurance retention is below bottom of the cover on risk, ILF(ER) is replaced with ILF(E)
- When top of reinsured layer is beyond the top of the cover on risk, ILF(ER+LR) becomes ILF(E+L)
- When reinsurance layer finishes below risk (0% reinsured)
- When reinsurance layer starts above cover on risk (0% reinsured)

Practical considerations in exposure rating –

1. Reinsurers might have **limited historical loss data**
2. Pricing of high excess layers reinsurance is derived by **minimum rate requirement**
3. In some cases, cedant **does not provide individual risk information**
4. When this happens, reinsurer needs to make a **judgement** on where in the interval the limit actually lies.

Non-Proportional Reinsurance Pricing – Experience Rating

We may use the following approaches for experience rating:

1. Burning cost method
2. Frequency-severity method

Burning Cost Approach

The common steps involved in pricing a non-proportional reinsurance treaty using burning cost approach are:

1. Reinsurer first applies **trends** to historical loss data.
2. The format of this data depends on **type of cover** (LOD/RAD)
3. The loss data from insurer must be **from ground-up** and uncapped.
4. Trends would be applied to past paid claims and case reserves.
5. Then, **reinsurance terms** would be applied to trended losses
6. Trended losses to be used to fit statistical methods to find ultimate
7. If data is limited, **benchmark data** is used
8. Now, consider relevant **exposure measure** i.e., premium/SI
9. Historical premiums to be adjusted to find **'as-if' premiums**
10. Exposure measure also needs to be adjusted for **inflation**
11. We bring losses and exposure on common level
12. Estimate loss costs by averaging losses to layer for all years or estimating lost cost rate for all years and then averaging them.
13. We then need to estimate any **trends in loss cost**
14. Final loss cost rate to be determined with **underwriters**

Frequency Severity Approach

This method involves the following steps:

1. Losses are adjusted for trends
2. Development for open claims in recent years to be considered
3. Applying aggregate development factors to individual claims might understate variability
4. IBNER to be estimated for open, non-settled claims
5. Large loss count development may be used to estimate IBNR
6. Frequency & Severity distributions to be combined

Practical Issues in Non-Proportional Reinsurance Pricing

Following practical issues may arise in non-proportional reinsurance pricing:

- Reporting threshold for large loss data
- Choice of inflation rates
- Treatment of shock losses
- Discounting of future loss costs
- Changes in cedant business mix

Proportional Reinsurance Pricing

In proportional reinsurance pricing, the task is not to find premium rate, but rather to:

- Assess likely overall loss ratio
- Determine the level of ceding/ profit commission that may be offer

Assessment of Overall Loss Ratio

The steps involved in assessing overall loss ratio include:

1. Collecting Data
2. Projecting ultimate claims for each year and calculate loss ratios
3. Trends may be applied to loss ratios to reflect for upcoming period
4. An estimate of overall loss ratio is made based on various methods

Determining level of ceding/profit commission

If the ceding commission is flat and there is no profit commission, the reinsurer would check if

$$\textbf{100} - \textbf{loss ratio}\% - \textbf{ceding commission}\%$$

Leaves enough for profits and other expenses of the reinsurer. When there is a sliding scale ceding commission or a profit commission with flat ceding commission, loss ratio distribution would be needed to estimate the reinsurer's financial position distribution.

Surplus Share Reinsurance Pricing

Surplus share contracts may be modelled similar to Quota Share treaties. However, an important complication is that the loss ratio or claims experience might be different for insurer and reinsurer. Reinsurer's experience is dependent on the way in which large losses are distributed. Risks with higher limits, and therefore higher cession rates will have much larger losses than those with lower cession. Here, the ceded loss ratio is higher than original loss ratio. The opposite of this is also true. Reinsurer therefore needs to be confident about:

- Large limit risks not having disproportionately heavy large loss experience
- Contracts terms restricting choices a cedant makes about amount ceded

The risk data therefore needs to be used to assess the likely distribution of cession rates.

Stop Loss Reinsurance Pricing

Stop Loss reinsurance is priced in a similar way to an excess of loss reinsurance, except loss ratios are used as attachment and detachment points rather than monetary amounts.

Pricing other features of Reinsurance Contract

While pricing a reinsurance treaty, certain complicated and unusual features of the treaty need to be adjusted for. Examples of few are:

- Reinstatement Premiums
- Aggregate deductibles
- Indexation clauses
- Swing Rates
- Loss Ratio Caps

CATASTROPHE MODELS

Catastrophe v/s Traditional Models

Traditional pricing methods like Frequency-Severity and Burning Cost method work well for high-frequency low severity risks but not for **low-frequency high-severity risks**. The reason being that past loss data may be too limited to reflect the true risk, because the **return period of losses is much longer** than the observation period. CAT models estimate losses based on insured's geographical locations.

Structure of Catastrophe Models

All catastrophe models follow a same generic structure, consisting of following interlinked modules:

Event Module – This module is a database of stochastic events.

Hazard Module – This module consists of hazard of each event.

Inventory Module – This module consists of all details regarding insured's risks and associated risk factors.

Vulnerability Module – This module measures how much damage each insured item is likely to sustain a peril.

Financial Analysis Module – This module consists of policy conditions like limits, excess, coverage terms, etc.

Key Perils Modelled

Common perils modelled in catastrophe models are:

- Hurricane
- Earthquake
- Tornadoes
- Hailstorms
- Winterstorms
- Floods
- Diseases
- Non-natural perils