FINANCIAL RISK MANAGEMENT HANDBOOK

A MANUAL OF FINANCIAL RISK MANAGEMENT PRACTICES

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I. STRUCTURE OF RISK AND RISK CATEGORIS

(Theories, Concepts and Practices)

I. Definition of Risk

Risk is the potential that a chosen action or activity, including the choice of inaction will lead to a loss or an undesirable outcome. Therefore, in simplified terms risk can be defined as effect of uncertainty on objectives. Risk has two components in its anatomy namely *Exposure* and *Uncertainty*. In order to be in risk, you need to be exposed and there need to be some kind of uncertainty as to what will be happen.

1. Exposure

Exposure refers to the maximum amount you tend to lose in the worst-case scenario. Your exposure should essentially be a positive number.

2. Uncertainty

Uncertainty refers to the probability that worst case scenario will happen. Uncertainty should be greater than 0 and less than 1. In terms of theory, 0 probability means non-existent and 1 probability means certainty.

Financial Risk is often defined as the unexpected variability or volatility of returns and thus includes both potential worse-than-expected as well as better-than-expected returns. The basic formula to calculate a financial risk or any kind of risk is as follows:

Risk = Exposure x Uncertainty, or in simple mathematical terms, Risk = Expected Loss x Probability of Loss.

II. Categories of Risk

All kind of risks are philosophically divided into 3 main categories i.e. systematic risks, unsystematic risks and fidelity risks.

1. Systematic Risks

These are the risks that are a part of system and any single business entity can neither influence them nor change them because these risks are derived from macro environment. Examples of these kinds of risks include inflation risk, taxation risks, regulation risks, demand risks, supply risks, interest rate risks etc.

2. Unsystematic Risks

These are the risks that are a part of business and arise from the particular nature and operations of a business entity. These risks can be changed and influenced by the business entity. Examples of these kinds of risks include equity risks, credit risks, capital risks, valuation risks etc.

3. Fidelity Risks

Fidelity risks are risks arising from either incorrect or incomplete information. In today's dynamic environment, businesses make decisions on the basis of available market information. If the information is incorrect or incomplete, this will lead to wrong business decision resulting in losses. Fidelity risk is part systematic and part unsystematic, therefore, it is treated as a separate category.

II. FUNDAMENTALS OF RISK MEASUREMENT

(Theories, Concepts and Practices)

I. Measurement of Risk

Risk Measurement is the process of assigning a numerical value to the random variable representing an uncertain payoff. Risks are quantified by using many different methodologies. One particular risk can be measured by several different formulae depending upon the data availability and valuation approach. The number obtained after the measurement of a risk is called *Risk Metric* which represents the quantum of a risk. Any risk measurement should have following 5 basic properties in order to be called a coherent risk measure:

1. Non-Negativity

This means that the risk value will never be negative or less than zero.

2. Monotonicity

This means that if portfolio A always has better values than portfolio B under all scenarios, then the risk of A should be less than the risk of B.

3. Sub-Additivity

This means that the risk of two portfolios together cannot get any worse than adding the two risks separately.

4. Positive Homogeneity

This means that if you double your portfolio then you double your risk.

5. Translation Invariance

This means that if the value A is just adding cash to your portfolio Z, which acts like an insurance then the risk of Z + A will be less than the risk of Z and the difference is exactly the added cash A.

II. FUNDAMENTALS OF RISK MANAGEMENT

(Theories, Concepts and Practices)

I. Management of Risk

All kind of risks, whether financial or non-financial, are managed by using 4 main methods. These methods include avoidance of risk, reduction of risk, insurance of risk and absorption of risk.

1. Risk Avoidance

The simplest way to manage risk is to avoid risk altogether and not do the activity which entails a risk. For example, the perfect way to avoid a credit risk is to not give credit at all. However, if real world when your business is giving credit, there is no way you can adopt this methodology without closing down your business. This type of methodology is applicable in operational risk management where you change or modify your operation methods to avoid certain type of risk altogether. For example, if there is a risk that your cashier may steal money from your store, you can completely avoid this risk by sitting on cash counter yourself. Hence, you avoided a risk by modifying the way you operate.

2. Risk Reduction

This group of risk management methodology includes internal operational practices that help in reducing the probability of risk occurrence. For example, in case of default risk, a bank can make strict internal policies to give credit to only highly rated companies and customers based on either external credit ratings or internal credit scoring. This way bank will be giving credit to only credible parties thereby reducing the probability of default on its credit exposure.

3. Risk Insurance

This group of risk management methodology includes investment in external instruments that insures the risk exposure in worst case scenario. The main purpose is that if risk materializes then the insurer will bear the cost of loss just like fire insurance or life assurance. This methodology has a cost which is called a premium that a business entity has to pay to its insurer. Examples of risk insurance include forward contracts, future contracts, swap contracts and option contracts etc.

4. Risk Absorption

If none of the above methodology can be used than the last option is to just accept the risk and live with it. This involves including the cost of risk in your business cost calculations. This increases the cost of operations and reduces the operating profit.

II. Categories of Financial Risks

Financial risk is an umbrella term for any risk associated with any form of financing. Risk may be taken as downside risk, the difference between the actual return and the expected return (when the actual return is less), or the uncertainty of that return.

Risk related to an investment is often called investment risk. Risk related to a company's cash flow is called business risk.

A science has evolved around managing market and financial risk under the general title of modern portfolio theory initiated by Dr. Harry Markowitz in 1952.

In financial sector the main categories of financial risks include market risks, credit risk and capital risks representing the 3 main component of balance sheet. This is based on the fact that the biggest risk for any business is the risk of insolvency resulting from balance sheet failure which represents a situation whereby business losses are greater than what balance sheet can absorb thereby wiping out the business capital.

1. Market Risks (Asset Side Risks)

Market risks represent the risk of reduction of market value of assets and investment on balance sheet. This includes both short term and long-term assets.

2. Credit Risks (Asset Side Risks)

Credit risks represent the risk of default from counter parties on their payables to business. This includes both short term and long-term receivables on balance sheet.

3. Solvency Risks (Liability Side Risks)

Solvency risks represent the risk that business losses will be greater than what can be absorbed by the capital side of balance sheet, thereby reducing capital from required level and making business insolvent.

MARKET RISK

(Theory, Calculations and Practical Concepts)

I. Definition of Market Risk

Market risk is exposure to the uncertain market value of a portfolio. A person holds a portfolio of equity shares. He knows what the market value of his shares is today, but he does not know what the market value will be tomorrow. He faces market risk.

Market risk in simplified terms is the risk that the value of a portfolio, either an investment portfolio or a trading portfolio, will decrease due to the change in value of the market risk factors.

1. Standard Market Risks

The four standard market risk factors are stock prices, interest rates, foreign exchange rates, and commodity prices therefore; the 5 basic associated market risks are equity risks, interest rate risks, liquidity risk, currency risks and commodity risks.

i. Equity Risk

Equity risk is the risk that stock prices and/or the implied volatility will change.

ii. Interest Rate Risk

Interest Rate Risk is the risk that interest rates and/or the implied volatility will change.

iii. Liquidity Risk

Liquidity Risk represent the risk that a given security or asset cannot be traded quickly enough in the market to prevent a loss or make the required profit. This is essentially a sub set of market risk but it is treated as a separate class of risk.

iv. Currency Risk

Currency Risk is the risk that foreign exchange rates and/or the implied volatility will change.

v. Commodity Risk

Commodity Risk is the risk that commodity prices and/or the implied volatility will change.

Volatility is a measure of uncertainty. It reflects the tendency of the value of an asset to fluctuate either up or down. Volatility can only suggest the magnitude of fluctuation but not the direction of the movement. Volatility is represented as annualized percentage. Higher volatility means higher fluctuations and lower volatility means lower fluctuations. There are two types of volatilities i.e. Historic Volatility and Implied Volatility. *Historic Volatility* is a measure of fluctuations in the value of an asset during past 30 days and *Implied Volatility* is a measure of fluctuations in the value of an asset during future 30 days.

II. Measurement of Market Risk - (Market Risk Metrics)

Market risk is measured by various different measurement methodologies representing different metrics. Given below are the definitions and calculation methodologies of ten most important market risk metrics that are popular in modern risk management practices:

1. Standard Deviation

Standard deviation is a widely used metric of variability or diversity used in statistics and probability theory. It shows how much variation or "dispersion" there is from the average (mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values. High standard deviation means high risk and low standard deviation means low risk. Standard Deviation is calculated as a number and represented by σ (pronounced *Sigma*).

Standard Deviation is calculated by following simple steps:

1. Calculate the mathematical mean of data which is represented by μ (pronounced *Meu*).
2. Calculate the difference of each data point from the mean of data by subtracting each data point from mean i.e. X - μ.
3. Take the Square of each value of X - μ in order to convert all values to a positive number as some of the values may be negative i.e. (X - μ) ^2.
4. Add all the values of (X - μ) ^2.
5. Take a Square Root of the sum of (X - μ) ^2.

Mathematical Formula for the calculation of Standard Deviation is under:

$$\sigma = \sqrt{\mathrm{E}\left[(X - \mu)^2\right]}.$$

Where:
σ = Standard Deviation
E = Sum
X = Data Points
μ = Mean

2. Absolute Deviation

Absolute Deviation of a data set is the absolute difference between data points and a selected point. Typically, the point from which the deviation is measured is a measure of Central Tendency, most often the Median or sometimes the Mean of the data set. High absolute deviation means high risk and low absolute deviation means low risk. Absolute Deviation is calculated as a number and it is represented by Di.

Central Tendency refers to the central value of a data set which is represented commonly by mean, median or mode. *Mean* refers to mathematical average of data; *Median* refers to the middle value that separates the higher half from the lower half of the data set when data is placed in ascending or descending order and; *Mode* is the most frequent value in the data set.

Mathematical Formula for the calculation of Absolute Deviation is under:

$$D_i = | x_i - m(X) |$$

Where:
Di = Absolute Deviation
Xi = Data Point
m(X) = Chosen measure of Central Tendency, mostly Median.

3. Value at Risk – VaR

Value at Risk (VaR) is a widely used risk measure of the risk of loss on a specific portfolio of financial assets. VaR was introduced by J P Morgan in 1994 and it became very popular measure of market risk among financial institutions and regulators worldwide within few years. VaR represents the maximum mark-to-market loss of a liquid portfolio value over a short-term future with a certain confidence level. Short term future can range from one day to ten 30 days and confidence level can range from 90% to 99.5%.

For example, if a portfolio of stocks has a one-day 95% VaR of $1 million, this means there is a 0.05 probability that the portfolio will fall in value by more than $1 million over a one-day period, assuming markets are normal and there is no trading. A loss which exceeds the VaR threshold is termed a *VaR Break*.

VaR is applicable to any liquid portfolio, that is, any portfolio that can reasonably be marked to market on a regular basis. VaR is not applicable to illiquid assets, such as real estate or fine art. VaR considers a portfolio's performance over a specific horizon i.e. a trading day, two weeks, a month, etc. This is called the *VaR Horizon*. VaR is measured in a particular currency. This is called the *Base Currency*. VaR also assumes normal market conditions and no trading in portfolio. VaR also totally ignores the impact of any kind of hedging. Finally, the portfolio's market risk is summarized with a single number. Informally, we called this a parameter of the distribution of portfolio value. More formally, it is any function of both the portfolio's current value and its random value at the end of the VaR horizon.

VaR belongs to the family of Quantile-based Risk Measurement. VaR is not sub-additive, hence not a coherent risk measure. VaR has monotonicity, positive homogeneity and translation invariance properties.

VaR is calculated with the following 5 base assumptions:

- Market Value of investment portfolio has *Standard Normal Distribution*.
- Investment portfolio is totally liquid.
- There is no *Hedging* in investment portfolio.
- There is no trading in investment portfolio.
- Market conditions are normal i.e. no crisis.

It is important to understand the concept of Standard Normal Distribution before understanding the calculation of VaR.

i. Standard Normal Distribution

The Normal or Gaussian distribution is a continuous probability distribution that is often used as a first approximation to describe real-valued random variables that tend to cluster around a single mean value. The graph of the associated probability density function is "bell"-shaped, and is known as the Gaussian function or bell curve.

Where parameter μ is the mean (location of the peak) and σ 2 is the variance (the measure of the width of the distribution). The distribution with mean μ = 0 and standard deviation σ = 1 is called the Standard Normal Distribution.

$$f(x) = \frac{e^{-(x-\mu)^2} / \left(2\sigma^2\right)}{\sigma\sqrt{2\pi}}$$

μ = mean
σ = standard deviation

Simply speaking, a standard normal distribution of continuous distribution of a value shows that the extent & pattern to which value can appreciate is exactly equal to the extent & pattern to which this value can depreciate. For example, if current value of a share is $5 and it has standard normal distribution which limit of +$3, this means the value of share can go up to $8 i.e. ($5 + $3), or go down to $2 i.e. ($5 - $3). The higher the value can go, the lower it can go if things go wrong. This actually defines the concept of high risk and high return in mathematical terms.

ii. Mathematics of VaR

Mathematically speaking, VaR shows 2 things. The Confidence Level of calculation and calculated Potential Loss of a portfolio. *Confidence Level* is shown as percentage i.e. 95% VaR = $2 million. Here 95% means that calculated VaR is accurate in 95% cases of normal market conditions or simply speaking it means that there is 95% probability that your loss will not be more than potential loss of $2 million and there is only 5% probability that potential loss will be more than $2 million.

Common confidence levels for One Day VaR and One Week VaR horizons are 99% and 95% respectively. Although VaR virtually always represents a loss, VaR is conventionally reported as a positive number. A negative VaR would imply the portfolio has a high probability of making a profit. For example, a 95% VaR of - $5 million means there is 95% probability that the portfolio value would increase by $5 million.

Risk measurement VaR is sometimes called parametric VaR. This usage can be confusing, however, because it can be estimated either parametrically (for examples, variance-covariance VaR or delta-gamma VaR) or non-parametrically (for examples, historical simulation VaR or resampled VaR). The inverse usage makes more logical sense, because risk management VaR is fundamentally nonparametric, but it is seldom referred to as nonparametric VaR. Mathematically speaking, VaR can be defined as "Given some confidence level α (0,1) the VaR of the portfolio at the confidence level α is given by the smallest number *l* such that the probability that the loss L exceeds *l* is not larger than (1 − α)".

$$\mathrm{VaR}_\alpha(L) = -\inf\{l \in \Re : P(L > l) \le 1 - \alpha\} = -\inf\{l \in \Re : F_L(l) \ge \alpha\}$$

The left equality is a definition of VaR. The right equality assumes an underlying probability distribution, which makes it true only for parametric VaR.

iii. VaR Calculation

Assume you hold $100 million worth of shares of a particular company. Current market value of these shares is $100 million. But you can lose if market value goes down tomorrow. How much the market value of this portfolio will change in a month? Without an answer to this question, investors have no way to decide whether the returns they receive are appropriate compensation for risk.

To answer this question, we first have to analyze the historic market value of these shares. Assume only 24 months value changes are available which are 3%, -2%, -3%, 4%, 5%, -1%, -2%, 1%, 2%, 3%, -1%, -3%, -2%, 3%, 4%, 2%, 3%, -3%, 2%, 3%, 1%, -1%, 2%, -1%.

Change in value of this portfolio ranged from a low of -3% to a high of +5% during last 24 months. Now construct regularly spaced ``buckets'' going from the lowest to the highest number and count how many observations fall into each bucket. By so doing, you will construct a ``probability distribution'' for the monthly returns, which counts how many occurrences have been observed in the past for a particular range. Distribution Plot is as follows:

Value Change	**Frequency**	**Probability**	**Cumulative Probability**
-1%	4	0.17 = (4/24)	1.00
-2%	3	0.13 = (3/24)	0.84
-3%	3	0.13 = (3/24)	0.71
1%	2	0.08 = (2/24)	0.58
2%	4	0.17 = (4/24)	0.50
3%	5	0.21 = (5/24)	0.33
4%	2	0.08 = (2/24)	0.12
5%	1	0.04 = (1/24)	0.04
Total	**24**	**1.00**	

For each return, you can then compute a probability of observing a lower return. Pick a confidence level, say 70%. For this confidence level, you can find on the graph a point that is such that there is a 30% probability of finding a lower return. This number is -3%, as all occurrences of returns less than -3% add up to 29% of the total number of months, or 7 out of 24 months.

Therefore, you are now ready to compute the VAR of a $100 million portfolio. There is only a 30% chance that the portfolio will fall by more than $100 million times -3%, or $3 million. Therefore VaR 70% is $3 million. In other words, the market risk of this portfolio can be communicated effectively to a non-technical audience with a statement such as: Under normal market conditions, the most the portfolio can lose over a month is $3 million in 70% cases.

One needs software to calculate VaR as at least 5 years daily data of value change is required. All models of VaR effectively use the same methodology which is described above.

iv. VaR Models

Value at Risk (VaR) has become the standard measure that financial analysts use to quantify market risk. VaR is defined as the maximum potential loss in value of a portfolio due to adverse market movements, for a given probability. The great popularity that this instrument has achieved is essentially due to its conceptual simplicity: VaR reduces the (market) risk associated with any portfolio to just one number, the loss associated to a given probability.

While VaR is a very easy and intuitive concept, its measurement is a very challenging statistical problem. Although the existing models for calculating VaR employ different methodologies, they all follow a common general structure, which can be summarized in three points:

- Mark-to-market the portfolio.
- Estimate the distribution of portfolio returns.
- Compute the VaR of the portfolio.

In order to do the above, any VaR model will have to calculate the following:

- The specifications of variance equation.
- The distribution of financial data.
- The calculation of standardized residual.

The main differences among VaR methods are related to point 2 that is the way they address the problem of how to estimate the possible changes in the value of the portfolio. All the existing VaR models can be classified into three broad categories:

- Parametric (RiskMetrics and GARCH)
- Nonparametric (Historical Simulation and the Hybrid model)
- Semi Parametric (Extreme Value Theory, CAViaR and quasi-maximum likelihood GARCH)

a. Parametric Models

All parametric models assume some kind of distribution pattern of financial data. The most common assumption is Standard Normal Distribution or Exponential Distribution of financial data. The general finding is that these approaches (both normal GARCH and RiskMetrics) tend to underestimate the Value at Risk, because the normality assumption of the standardized residuals seems not to be consistent with the behavior of financial returns. The main advantage of these methods is that they allow a complete characterization of the distribution of returns and there may be space for improving their performance by avoiding the normality assumption.

Statistically, a parametric model is one in which the indexing parameter is a finite-dimensional vector.

b. Non-Parametric Models

Non-Parametric Models do not assume any distribution pattern of financial data. One of the most common methods for VaR estimation is the Historical Simulation. This approach drastically simplifies the procedure for computing the Value at Risk, since it doesn't make any distributional assumption about portfolio returns. Historical Simulation is based on the concept of rolling windows. First, one needs to choose a window of observations, which generally ranges from 6 months to two years. Then, portfolio returns within this window are sorted in ascending order and the θ-quantile of interest is given by the return that leaves θ % of the observations on its left side and (1-θ) % on its right side. If such a number falls between two consecutive returns, then some interpolation rule is applied. To compute the VaR the following day, the whole window is moved forward by one observation and the entire procedure is repeated.

Even if this approach makes no explicit assumptions on the distribution of portfolio returns, an implicit assumption is hidden behind this procedure: the distribution of portfolio returns doesn't change within the window. From this implicit assumption several problems derive.

First, this method is logically inconsistent. If all the returns within the window are assumed to have the same distribution, then the logical consequence must be that all the returns of the time series must have the same distribution.

Second, the empirical quantile estimator is consistent only if k, the window size, goes to infinity.

The third problem concerns the length of the window. This is a very delicate issue, since forecasts of VaR under this approach are meaningful only if the historical data used in the calculations have (roughly) the same distribution. In practice, the volatility clustering period is not easy to identify. The length of the window must satisfy two contradictory properties: it must be large enough, in order to make statistical inference significant, and it must not be too large, to avoid the risk of taking observations outside of the current volatility cluster. Clearly, there is no easy solution to this problem.

Moreover, assume that the market is moving from a period of relatively low volatility to a period of relatively high volatility (or vice versa). In this case, VaR estimates based on the historical simulation methodology will be biased downwards (correspondingly upwards), since it will take some time before the observations from the low volatility period leave the window.

Statistically, in nonparametric models, the set of possible values of the parameter θ is a subset of some space, not necessarily finite dimensional.

c. Semi Parametric Models

A Semi Parametric Model for observational data combines a parametric form for some component of the data generating process (usually the behavioral relation between the dependent and explanatory variables) with weak nonparametric restrictions on the remainder of the model (usually the distribution of the unobservable errors).

Statistically, In Semi Parametric Models, the parameter has both a finite dimensional component and an infinite dimensional component, often a real-valued function defined on the real line.

4. Conditional VaR – Expected Short Fall (ES)

Conditional VaR (CVaR) or Expected shortfall (ES) is a risk measure, a concept used in finance and more specifically in the field of financial risk measurement to evaluate the market risk or credit risk of a portfolio. It is an alternative to Value at Risk and it is more sensitive to the shape of the loss distribution in the tail of the distribution. The "expected shortfall at q% level" is the expected return on the portfolio in the worst q% of the cases. It is also called Average Value at Risk (AVaR), and Expected Tail Loss (ETL).

Simply speaking, VaR measures value of loss at a certain confidence level assuming potential losses are normally distributed and conditional VaR measures the value of loss that is beyond VaR horizon. It represents the worst-case losses assuming values after VaR Horizon.

Expected shortfall is a coherent, and moreover a spectral, measure of financial portfolio risk. It requires a quantile-level q, and is defined to be the expected loss of portfolio value given that a loss is occurring at or below the q-quantile.

i. Calculation of Conditional VaR

Let's assume we have portfolio which has a market value of $100. Using VaR we constructed following table of probability of changes in value:

Probability	Value Change	Ending Value of Portfolio
10%	-100	0
30%	-20	80
40%	0	100
20%	+50	150

From this table let us calculate the CVaR*q* for a few (arbitrarily chosen) values of *q*:

q	CVaR
5%	-100
10%	-100
20%	-60
40%	-40
100%	-6

To understand how these values are calculated, let's take example of *q*20% which gives a value of CVaR or Expected Loss of $60. This is calculated as follows:

$$\frac{\frac{10}{100}(-100) + \frac{10}{100}(-20)}{\frac{20}{100}} = -60.$$

Therefore, simple formula will be:

Probability of q1 (q1 Value) + Probability of q2 (q2 Value) / Probability of q1 + q2

Similarly for any value of *q*, we can select as many rows starting from the top as are necessary to give a cumulative probability of q and then calculate an expectation over those cases. The expected shortfall ESq or CVaR increases as q increases.

For a given portfolio the expected shortfall ESq is worse than (or equal) to the Value at Risk VaRq at the same q level. The 100%-quantile expected shortfall ES1.0 equals the Expected value of the portfolio.

5. Marginal VaR
The Marginal VaR of a position with respect to a portfolio can be thought of as the amount of risk that the position is adding to the portfolio. It can be formally defined as the difference between the VaR of the total portfolio and the VaR of the portfolio without the position.

To measure the effect of changing positions on portfolio risk, individual VaRs are insufficient. Volatility measures the uncertainty in the return of an asset, taken in isolation. When this asset belongs to a portfolio, however, what matters is the contribution to portfolio risk.

6. Incremental VaR
Incremental VaR provides information regarding the sensitivity of portfolio risk to changes in the position holding sizes in the portfolio.

An important property of incremental risk is sub-additivity. That is, the sum of the incremental risks of the positions in a portfolio equals the total risk of the portfolio. This property has important applications in the allocation of risk to different units, where the goal is to keep the sum of the risks equal to the total risk.

Incremental statistics also have applications to portfolio optimization. A portfolio with minimum risk will have incremental risk equal to zero for all positions. Conversely, if the incremental risk is zero for all positions, the portfolio is guaranteed to have minimum risk only if the risk measure is sub additive.

7. Downside Risk – Sortino Ratio
The Sortino ratio measures the risk-adjusted return of an investment asset, portfolio or strategy. It is a modification of the Sharpe ratio but penalizes only those returns falling below a user-specified target, or required rate of return, while the Sharpe ratio penalizes both upside and downside volatility equally.

It is thus a measure of risk-adjusted returns that treats risk more realistically than the Sharpe ratio. The Sortino Ratio formula is as follows:

$$S = \frac{R - T}{DR},$$

Where,
S = Portfolio's Realized Returns
T = Target Returns
DR = Downside Risk

The downside risk is the target semi deviation or square root of the target semi variance (TSV). TSV is the return distribution's lower-partial moment of degree 2 (LPM2). DR is calculated as follows:

$$DR = \left(\int_{-\infty}^{T} (T - x)^2 f(x)\, dx \right)^{1/2},$$

Where T is often taken to be the risk-free interest rate and f() is the probability density function of the returns. This can be thought of as the root mean squared underperformance, where the underperformance is the amount by which a return is below target (and returns above target are treated as underperformance of 0).

Thus, the ratio is the actual rate of return in excess of the investor's target rate of return, per unit of downside risk; or, over performance divided by root-mean-square underperformance. The ratio was created by Brian M. Rom in 1986

8. Greeks

Greeks also known as 1^{st} Order Greeks are sensitivity calculations in financial risk management. Each Greek is a ratio that measures the sensitivity of the portfolio value in relation to a change in a given factor. Simply speaking each Greek measures how the portfolio's market value will change due to a change in some variable.

There are 5 basic Greeks i.e. *Delta, Gamma, Vega, Theta* and *Rho.* They are called the Greeks because four out of the five are named after letters of the Greek alphabet. Vega is the exception and for reasons unknown, it is named after the brightest star in the constellation Lyra.

The basic concept of *Options* needs to be understood before understanding Greeks.

An Option is a contract that gives the buyer the right, but not the obligation, to buy or sell an asset at a specific price on or before a certain date. An option, just like a stock or bond, is a security. It is also a binding contract with strictly defined terms and properties. The price at which an asset can be purchased or sold is called the *Strike Price*. This is the price a stock price must go above for calls or go below for puts before a position can be exercised for a profit. All of this must occur before the Expiration Date which is the date on which option can be exercised as per option contract.

The two types of options are *Call Options* and *Put Options.*

A Call Option gives the holder the right to buy an asset at a certain price within a specific period of time. Calls are similar to having a long position on a stock. Buyers of calls hope that the stock will increase substantially before the option expires.

A Put Option gives the holder the right to sell an asset at a certain price within a specific period of time. Puts are very similar to having a short position on a stock. Buyers of puts hope that the price of the stock will fall before the option expires. There are four types of participants in options markets depending on the position they take:

- Buyers of calls
- Sellers of calls
- Buyers of puts
- Sellers of puts

People who buy options are called holders and those who sell options are called writers; furthermore, buyers are said to have long positions, and sellers are said to have short positions.

For call options, the option is said to be *In-The-Money* if the share price is above the strike price. Which means you can earn a profit by exercising the option. Similarly, a put option is in-the-money when the share price is below the strike price. The amount by which an option is in-the-money is referred to as *Intrinsic Value*. If the share price is equal to the strike price, the option is called to be *At-The-Money*.

The total cost or the price of an option is called the *Premium*. This price is determined by factors including the stock price, strike price, time remaining until expiration, which is time value and volatility.

i. Delta

Delta Δ, measures the rate of change of option value with respect to changes in the underlying asset's price. Delta is the first derivative of the value V of the option with respect to the underlying instrument's price S. Formula for Delta is as under:

$$\Delta = \frac{\partial V}{\partial S}$$

Simply speaking it means:
(New Price of Option – Old Price of Option) / (New Value of Underlying Asset – Old Value of Underlying Asset)

Delta value is the most well-known and the most important of the option Greeks. It is the degree to which an option price will move given a change in the underlying stock price, all else being equal. In layman terms, delta is that options Greek which tells you how much money a stock option will rise or drop in value with a $1 rise or drop in the underlying stock, which also translates to the amount of profit you will make when the underlying stock rises. This means that the higher the delta value a stock option has, the more it will rise with every $1 rise in the underlying stock. Stock options with options delta of 0.7 is expected to raise $0.70 with a $1 rise in the underlying stock. Stock options value is affected most by changes in the price of the underlying stock, making delta value of stock options the single most important options Greeks to understand in options trading.

Delta values are number between 0.00 and 1.00. For example, an option with a delta of 0.5 will move half a cent for every one cent movement in the underlying stock, or in other words value of option will move by 50% of the value of underlying stock. Which means, stock options with a higher delta will increase / decrease in value more with the same move on the underlying stock versus stock options with a lower delta value.

Options delta values are either positive or negative. Call Options have *Positive Delta* values suggesting that it will gain in value proportionately with a gain in value in the underlying stock. Put Options have *Negative Delta* values suggesting that it will lose value as the underlying stock rises. Conversely, call options with its positive delta values drops in price as the underlying stock falls and put options with its negative delta values gains in price as the underlying stock falls. In short, positive delta value becomes profitable as the stock goes up and negative delta value becomes profitable as the stock goes down.

Options delta value changes as it gets more and more in the money or out of the money. This rate of change is governed by another option Greek known as Gamma.

ii. Gamma
Gamma Γ, measures the rate of change in the delta with respect to changes in the underlying price. Gamma is the second derivative of the value function with respect to the underlying price. All long options have positive gamma and all short options have negative gamma. Gamma is greatest right at-the-money (ATM) and diminishes the further out you go either in-the-money (ITM) or out-of-the-money (OTM). Gamma is important because it corrects for the convexity of value. Formula for Gamma is as under:

$$\Gamma = \frac{\partial \Delta}{\partial S} = \frac{\partial^2 V}{\partial S^2}$$

Just as options delta measures how much the value of an option changes with a change in the price of the underlying stock, Options Gamma describes how much the options delta changes as the price of the underlying stock changes. Of the 5 options Greeks, Delta and Gamma are the only ones that are related to each other and that Options Gamma is the only options Greek that describes the change of another Greek.

Options Gamma is important because it affects the single options Greek that determines the value of stock options most and that is the options delta. There is no question that options delta changes as it starts off at 0.5 when it is at-the-money and then gradually move towards 1 as the options go deeper in-the-money or gradually towards 0 as the options go farther out-of-money.

Options Gamma come in positive or negative polarity. *Positive Gamma* suggests that the delta of the option will increase as the underlying stock rises. *Negative Gamma* suggests that the delta of the option will decrease towards -1 as the underlying stock rises.

Options Gamma decreases towards 0 as the option moves deeper in-the-money or farther out-of-money. At-the-money options typically have the highest Options Gamma value. This also means that the delta value of deep in-the-money or far out-of-money options are less likely to change with a small change in the price of the underlying stock.

Options Gamma of at-the-money options increases as expiration draws nearer while Options Gamma of both in-the-money and out-of-money options decreases nearer to expiration.

iii. Vega

Vega *v*, measures the sensitivity of the value of option to the volatility of underlying asset. In other words, Vega calculates how much an option value would change when volatility changes by 1%. Formula for Vega is as under:

$$\nu = \frac{\partial V}{\partial \sigma}$$

Vega is typically expressed as the amount of money per underlying share that the option's value will gain or lose as volatility rises or falls by 1%.

Vega can be an important Greek to monitor for an option trader, especially in volatile markets, since the value of some option strategies can be particularly sensitive to changes in volatility.

A *Positive Vega* means the option price will increase when volatility increases and it will decrease when volatility decreases. Similarly, a *Negative Vega* means the option price will decrease when volatility increases and it will increase when volatility decreases.

Vega is higher when there is more time remaining to expiration. This makes sense because options with more time remaining for expiration have larger portion of time value, and it is the time value that is affected by the changes in volatility.

iv. Theta

Theta Θ, measures the sensitivity of the value of the derivative to the passage of time or the "time decay. Formula for Theta is as under:

$$\Theta = -\frac{\partial V}{\partial \tau}$$

The mathematical result of the formula for theta is expressed in value per year. By convention, it is usual to divide the result by the number of days in a year, to arrive at the amount of money per share of the underlying that the option loses in one day. Theta is almost always negative for long calls and puts and positive for short calls and puts. The total theta for a portfolio of options can be determined by summing the thetas for each individual position.

The value of an option can be analyzed into two parts: the intrinsic value and the time value. The *Intrinsic Value* is the amount of money you would gain if you exercised the option immediately, so a call with strike $50 on a stock with price $60 would have intrinsic value of $10, whereas the corresponding put would have zero intrinsic value. The *Time Value* is the value of having the option of waiting longer before deciding to exercise. Even a deeply out of the money put will be worth something, as there is some chance the stock price will fall below the strike before the expiry date. However, as time approaches maturity, there is less chance of this happening, so the time value of an option is decreasing with time. Thus, if you are long an option you are short theta: your portfolio will lose value with the passage of time keeping all other factors constant. Theta has highest value for at-the-money option, and it gradually lowers for in-the-money and out-of-money options.

v. Rho

Rho ρ, measures the change in option price due to change in interest rates. It is the derivative of the option value with respect to the risk-free interest rate. Except under extreme circumstances, the value of an option is less sensitive to changes in the risk-free interest rate than to changes in other parameters. For this reason, rho is the least used of the first-order Greeks. Formula for Rho is as under:

$$\rho = \frac{\partial V}{\partial r}$$

Rho is typically expressed as the amount of money, per share of the underlying, that the value of the option will gain or lose as the risk-free interest rate rises or falls by 1.0% per annum or 100 basis points.

Positive Rho means the option price will increase when interest rate increases and it will decrease when interest rate decreases. Similarly, a *Negative Rho* means the option price will decrease when interest rate increases and it will increase when interest rate decreases.

An increase in interest rate will increase the value of call option and decrease the value of put option. Similarly, a decrease in interest rate will decrease the value of call option and increase the value of put option.

For both call and put option, the longer the time to expiration, the larger is the impact of interest rate on the value of option. Usually out-of-money options have low Rho, while at-the-money and in-the-money options have high Rho.

9. Cross Greeks

Cross Greeks, also known as 2nd Order Greeks are sensitivity calculations in financial risk management. Each Cross Greek is a ratio that measures the sensitivity of the portfolio value in relation to a change in a given First Order Greek. Simply speaking each Cross Greek measures how the portfolio's market value will change due to a change in some Greek.

There 10 Cross Greeks which are commonly used in the calculations of risk metrics. Basic definitions of these 10 Cross Greeks are as under:

i. Charm

Charm or delta decay, measures the instantaneous rate of change of delta over the passage of time. Charm has also been called DdeltaDtime. Charm can be an important Greek to measure/monitor when delta-hedging a position over a weekend. Charm is a second-order derivative of the option value, once to price and once to the passage of time. It is also then the derivative of theta with respect to the underlying's price.

The mathematical result of the formula for charm is expressed in delta/year. It is often useful to divide this by the number of days per year to arrive at the delta decay per day.

This use is fairly accurate when the number of days remaining until option expiration is large. When an option nears expiration, charm itself may change quickly, rendering full day estimates of delta decay inaccurate.

$$\text{Charm} = -\frac{\partial \Delta}{\partial \tau} = \frac{\partial \Theta}{\partial S} = -\frac{\partial^2 V}{\partial S \, \partial \tau}$$

ii. Color

Color gamma decay or DgammaDtime measures the rate of change of gamma over the passage of time. Color is a third-order derivative of the option value, twice to underlying asset price and once to time. Color can be an important sensitivity to monitor when maintaining a gamma-hedged portfolio as it can help the trader to anticipate the effectiveness of the hedge as time passes.

The mathematical result of the formula for color is expressed in gamma/year. It is often useful to divide this by the number of days per year to arrive at the change in gamma per day. This use is fairly accurate when the number of days remaining until option expiration is large. When an option nears expiration, color itself may change quickly, rendering full day estimates of gamma change inaccurate.

$$\text{Color} = \frac{\partial \Gamma}{\partial \tau} = \frac{\partial^3 V}{\partial S^2 \, \partial \tau}$$

iii. DvegaDtime

DvegaDtime measures the rate of change in the Vega with respect to the passage of time. DvegaDtime is the second derivative of the value function; once to volatility and once to time.

It is common practice to divide the mathematical result of DvegaDtime by 100 times the number of days per year to reduce the value to the percentage change in Vega per one day.

$$\frac{\partial \nu}{\partial \tau} = \frac{\partial^2 V}{\partial \sigma \, \partial \tau}$$

iv. Gamma

Gamma Γ, measures the rate of change in the delta with respect to changes in the underlying price. Gamma is the second derivative of the value function with respect to the underlying price. All long options have positive gamma and all short options have negative gamma. Gamma is greatest right at-the-money (ATM) and diminishes the further out you go either in-the-money (ITM) or out-of-the-money (OTM). Gamma is important because it corrects for the convexity of value.

When a trader seeks to establish an effective delta-hedge for a portfolio, the trader may also seek to neutralize the portfolio's gamma, as this will ensure that the hedge will be effective over a wider range of underlying price movements. However, in neutralizing the gamma of a portfolio, alpha (the return in excess of the risk-free rate) is reduced.

$$\Gamma = \frac{\partial \Delta}{\partial S} = \frac{\partial^2 V}{\partial S^2}$$

v. Lambada

Lambada λ, omega, Ω, or elasticity is the percentage change in option value per percentage change in the underlying price, a measure of leverage, sometimes called gearing.

$$\lambda = \frac{\partial V}{\partial S} \times \frac{S}{V}$$

vi. Speed

Speed measures the rate of change in Gamma with respect to changes in the underlying price. This is also sometimes referred to as the gamma of the Gamma or DgammaDspot. Speed is the third derivative of the value function with respect to the underlying spot price. Speed can be important to monitor when delta-hedging or gamma-hedging a portfolio.

$$\text{Speed} = \frac{\partial \Gamma}{\partial S} = \frac{\partial^3 V}{\partial S^3}$$

vii. Ultima

Ultima measures the sensitivity of the option Vomma with respect to change in volatility. Ultima has also been referred to as DvommaDvol. Ultima is a third-order derivative of the option value to volatility.

$$\text{Ultima} = \frac{\partial \text{vomma}}{\partial \sigma} = \frac{\partial^3 V}{\partial \sigma^3}$$

viii. Vanna

Vanna, also referred to as DvegaDspot and DdeltaDvol, is a second order derivative of the option value, once to the underlying spot price and once to volatility. It is mathematically equivalent to DdeltaDvol, the sensitivity of the option delta with respect to change in volatility; or alternatively, the partial of Vega with respect to the underlying instrument's price. Vanna can be a useful sensitivity to monitor when maintaining a delta- or Vega-hedged portfolio as Vanna will help the trader to anticipate changes to the effectiveness of a delta-hedge as volatility changes or the effectiveness of a Vega-hedge against change in the underlying spot price.

$$\text{Vanna} = \frac{\partial \Delta}{\partial \sigma} = \frac{\partial \nu}{\partial S} = \frac{\partial^2 V}{\partial S \partial \sigma}$$

ix. Vomma

Vomma, Volga, Vega Convexity, Vega gamma or dTau/dVol measures second order sensitivity to volatility. Vomma is the second derivative of the option value with respect to the volatility, or, stated another way; Vomma measures the rate of change to Vega as volatility changes. With positive Vomma, a position will become long Vega as implied volatility increases and short Vega as it decreases, which can be scalped in a way analogous to long gamma. And an initially Vega-neutral, long-Vomma position can be constructed from ratios of options at different strikes. Vomma is positive for options away from the money, and initially increases with distance from the money (but drops off as Vega drops off). (Specifically, Vomma is positive where the usual d1 and d2 terms are of the same sign, which is true when $d2 > 0$ or $d1 < 0$.)

$$\text{Vomma} = \frac{\partial \nu}{\partial \sigma} = \frac{\partial^2 V}{\partial \sigma^2}$$

x. Zomma

Zomma measures the rate of change of gamma with respect to changes in volatility. Zomma has also been referred to as DgammaDvol. Zomma is the third derivative of the option value, twice to underlying asset price and once to volatility.

Zomma can be a useful sensitivity to monitor when maintaining a gamma-hedged portfolio as Zomma will help the trader to anticipate changes to the effectiveness of the hedge as volatility changes.

$$\text{Zomma} = \frac{\partial \Gamma}{\partial \sigma} = \frac{\partial \text{vanna}}{\partial S} = \frac{\partial^3 V}{\partial S^2\, \partial \sigma}$$

Given below is the table of all Greeks and Cross Greeks showing their relationships:

Due To Change In	Effect on				
FACTORS	**VLAUE**	**DELTA**	**VEGA**	**GAMMA**	**VOMMA**
Spot Price - S	Delta	Gamma	Vanna	Speed	
Volatility - σ	Vega	Vanna	Vomma	Zomma	Ultima
Time to Expiry - t	Theta	Charm	Dvega	Color	Totto
Risk Free Rate - r	Rho				

10. Measure of Five
Measure of Five is a set of 5 analytic which form the fundamentals of technical analysis of a portfolio risk measurement. Given below is the description of these 5 analytic:

i. Jensen Alpha
Jensen Alpha shows the difference between portfolio's returns and the expected returns from Cost of Equity as per Capital Asset Pricing Model (CAPM). The formula for Jensen Alpha is as under:

Jensen Alpha = Average Portfolio Returns – Cost of Equity

Where,
Cost of Equity = Risk Free Returns + Beta (Average Market Return – Risk Free Returns)

Jensen Alpha is calculated as a percentage and interpreted as follow:

- $\alpha_i < 0$: the investment has earned too little for its risk (or, was too risky for the return)
- $\alpha_i = 0$: the investment has earned a return adequate for the risk taken.
- $\alpha_i > 0$: the investment has a return in excess of the reward for the assumed risk.

ii. Beta
Beta (β) of a stock or portfolio is a number describing the relation of its returns with those of the financial market as a whole. An asset has a Beta of zero if its returns change independently of changes in the market's returns. A positive beta means that the asset's returns generally follow the market's returns, in the sense that they both tend to be above their respective averages together, or both tend to be below their respective averages together. A negative beta means that the asset's returns generally move opposite the market's returns: one will tend to be above its average when the other is below its average.

The beta coefficient is a key parameter in the *Capital Asset Pricing Model (CAPM*). It measures the part of the asset's statistical variance that cannot be removed by the diversification provided by the portfolio of many risky assets, because of the correlation of its returns with the returns of the other assets that are in the portfolio. Beta can be estimated for individual companies using regression analysis against a stock market index. Formula for Beta is as under:

$$\beta_a = \frac{\mathrm{Cov}(r_a, r_p)}{\mathrm{Var}(r_p)},$$

Where,

ra =	Rate of Return of Portfolio
rp =	Rate of return of Benchmark Portfolio
Cov (ra, rp) =	Covariance between the Rate of Returns

Beta is also referred to as financial elasticity or correlated relative volatility, and can be referred to as a measure of the sensitivity of the asset's returns to market returns, its non-diversifiable risk, its systematic risk, or market risk. On an individual asset level, measuring beta can give clues to volatility and liquidity in the marketplace. In fund management, measuring beta is thought to separate a manager's skill from his or her willingness to take risk.

iii. Treynor Ratio

The Treynor ratio, sometimes called the reward-to-volatility ratio or Treynor measure is a measurement of the returns earned in excess of that which could have been earned on an investment that has no diversifiable risk per each unit of market risk assumed. Formula for Treynor Ratio is as follows:

$$T = \frac{r_i - r_f}{\beta_i}$$

Where:

$T \equiv$ Treynor ratio,
$r_i \equiv$ Portfolio i's return,
$r_f \equiv$ Risk free rate
$\beta_i \equiv$ Portfolio i's beta

In simple terms:

Treynor Ratio = (Average Portfolio Returns – Risk Free Returns) / Portfolio Beta

The Treynor ratio relates excess return over the risk-free rate to the additional risk taken; however, systematic risk is used instead of total risk. Higher Treynor ratio means better performance of the portfolio under analysis.

iv. Sharpe Ratio

The Sharpe ratio or Sharpe index or Sharpe measure or reward-to-variability ratio is a measure of the excess return or risk premium per unit of risk in an investment asset or a trading strategy.

$$S = \frac{R - R_f}{\sigma} = \frac{E[R - R_f]}{\sqrt{\mathrm{var}[R - R_f]}},$$

Where,

R =	Portfolio Return
Rf =	Return on a Benchmark Portfolio
Σ =	Standard Deviation of the Excess of the Portfolio Return. Or Square Root of the Variance between Portfolio Returns and Returns on a Benchmark Portfolio

The Sharpe ratio is used to characterize how well the return of an asset compensates the investor for the risk taken, the higher the Sharpe ratio numbers the better. When comparing two assets each with the expected return E(R) against the same benchmark with return Rf, the asset with the higher Sharpe ratio gives more return for the same risk. Investors are often advised to pick investments with high Sharpe ratios.

v. Tracking Error

Tracking Error is a measure of how closely a portfolio follows the index to which it is benchmarked. Tracking Error is basically the Standard deviation of the difference between portfolio returns and benchmarked portfolio returns. Formula for tracking error is as follows:

$$T.E. = \omega = \sqrt{\mathrm{Var}(d-b)} = \sqrt{E[(d-b)^2] - (E[d-b])^2}$$

Where,

d = Portfolio Returns

b = Benchmark Portfolio Returns

Many portfolios are managed to a benchmark, normally an index. Some portfolios are expected to replicate, before trading and other costs, the returns of an index exactly (an index fund), while others are expected to 'actively manage' the portfolio by deviating slightly from the index in order to generate active returns or to lower transaction costs. Tracking error is a measure of the deviation from the benchmark; the replicated index fund would have a tracking error close to zero, while an actively managed portfolio would normally have a higher tracking error.

III. Management of Market Risk

Risk management provides 4 methods of managing risks i.e. risk avoidance, risk reduction, risk insurance and risk absorption. As risk avoidance and risk absorption are done on one time basis and do not require dynamic management of risk, therefore these are not included portfolio risk management theories. Similarly risk insurance pertains to only fixed assets and is done on a one-time basis, therefore it is also not included dynamic portfolio risk management. The most important method of risk management is risk reduction which pertains to current assets and is done on a continuous basis making it a part of dynamic portfolio risk management. Risk reduction methodologies constitute the biggest part in risk management practices and they are considered the most important in modern risk management. Whenever we talk about risk management, we are actually referring to risk reduction methodologies. Market risk is also managed through risk reduction.

Market risk is managed with a short-term focus through risk reduction methodology. Long-term losses are avoided by avoiding losses from one day to the next. On a tactical level, traders and portfolio managers employ a variety of risk metrics e.g. duration and convexity, the Greeks, beta, etc. to assess their exposures. These allow them to identify and reduce any exposures they might consider excessive.

On a more strategic level, organizations manage market risk by applying risk limits to traders' or portfolio managers' activities. Increasingly, value-at-risk is being used to define and monitor these limits. Some organizations also apply stress testing to their portfolios.

Risk reduction of market risk is conducted by *Derivatives*. A Derivative is a security whose price is dependent upon or derived from one or more underlying assets. The derivative itself is merely a contract between two or more parties. Its value is determined by fluctuations in the underlying asset. There are 5 basic types of derivatives i.e. Forwards, Futures, Swaps, Options and Swaptions.

All derivatives are valued on the basis of Break-Even Price. This refers to price at which neither the seller and nor the buyer will gain or lose any money. Therefore, all derivatives must have Zero value to start with.

1. Market Forwards

You have a share of a company which is worth $1 at today's market price and you want to sell it after 6 months. If market price of this share is more than $1 after six months, you will earn profit. But if the market price is lower than $1 after six months, you will incur a loss. How can you control this risk? Simple solution is to get into a Forward Contract.

A Forward Contract or simply a Forward is a non-standardized contract between two parties to buy or sell an asset at a specified future time at a price agreed today. This is in contrast to a *Spot Contract*, which is an agreement to buy or sell an asset today. It costs nothing to enter a forward contract. The party agreeing to buy the underlying asset in the future assumes a *Long Position*, and the party agreeing to sell the asset in the future assumes a *Short Position*. The price agreed upon is called the *Delivery Price*, which is equal to the *Forward Price* at the time the contract is entered into.

The forward price of such a contract is commonly contrasted with the *Spot Price*, which is the price at which the asset changes hands on the spot date. The difference between the spot and the forward price is the Forward Premium or Forward Discount, generally considered in the form of a profit, or loss, by the purchasing party. A Forward Premium or Forward Discount is the difference between the Spot Price and Delivery Price of an asset. If delivery price is more than spot price it is forward premium and if the delivery price is less than spot price, it is forward discount.

Forwards, like other derivative securities, can be used to hedge risk, as a means of speculation, or to allow a party to take advantage of a quality of the underlying instrument which is time-sensitive.

The value of a forward position at maturity depends on the relationship between the Delivery Price (K) and the underlying Spot Price (ST) at that time. Given below are the pay offs for long and short positions on a forward contract:

For a long position this payoff is: $fT = ST - K$
For a short position, it is: $fT = K - ST$

If the forward price is "fair" at initiation the contract is valueless and there is no immediate default risk. As time goes by, the forward price can change and existing forward contracts acquire value. They become an asset for one party and a liability for the other therefore, Default Risk appears. At any time only one of the counter-parties has the incentive to default. It is the counter-party for whom the forward contract has become a liability.

i. Valuation of Forward Contract

In order to understand valuation or pricing of a forward contract, we will assume a simple scenario. Assume that value of a 1-gram gold bar is $10 at the moment and you are selling a one year forward contract of $10 delivery price on it to your brother. This means that you are entering in a contract with some one that you will sell him one share of company A at $10 after one year to your brother. Now if the gold bar price after one year is $8, then you will buy gold bar from the market at spot price of $8 and sell it to your brother for $10 and earn a profit of $2. However, if the gold bar price after one year is $11, then you will buy gold bar from market at the spot price of $11 and sell it to your brother for $10 and book a loss of $1. The only way to insure that you neither gain any profit nor lose any money is to buy the gold bar at $10 immediately after signing the forward contract and keep it with you till one year. After one year no matter what is the spot price in the market, you will simply sell your gold bar to your brother which had cost you $10.

However theoretically speaking you will still incur a loss because you had incurred two costs. One is the cost of money as you had invested you $10 for one year. You could have kept your $10 in a bank and would have earned a Risk-Free Return for one year. Plus, there was a Carrying Cost for keeping gold bar safe for one year. Lets assume you could have earned Risk Free Return of $1 if you had kept your money in a bank for one year and the Carrying Cost of keeping gold bar in a bank's locker was $0.25 for the whole year. Therefore, you would be losing a total of $1.25 on this deal. The only solution to break even is to change the Delivery Price to $11.25 which will be the *Break-Even Price* of this forward contract. Because if your brother wants a 1-gram gold bar after one year and he want to make sure that gold bar does not cost him more than $10, he will have to buy gold bar today or else prices may change after one year and by doing so he will also incur an additional cost of $1.25 and the total transaction will cost him $11.25

Therefore, the price of contract will be:

Forward Contract Price = Spot Price of Asset X (Risk Free Return + Carrying Cost) ^ Delivery Time

$$F = S_0 \, e^{(q+r)T}$$

Where,

F = Price of Forward Contract
So = Spot Price of Underlying Asset (amount you need to invest now to purchase that asset)
q = Carrying Cost of Underlying Asset
r = Risk Free Rate of Return
T = Time to Delivery

A Forward Contract can become valuable to a buyer when spot price increases and it becomes a liability to a buyer when spot price decrease. Opposite is true for a seller. As forwards are binding contract therefore risk of default arises from the party who is losing money.

2. Market Futures

A futures contract is similar to a forward contract except for two important differences. First, intermediate gains or losses are posted each day during the life of the futures contract. This feature is known as Marking to Market. The intermediate gains or losses are given by the difference between today's futures price and yesterday's futures price. Second, futures contracts are traded on organized exchanges with standardized terms whereas forward contracts are traded over-the-counter which means customized one-off transactions between a buyer and a seller.

Although futures contracts require no initial investment like forward contracts, futures exchanges require both the buyer and seller to post a security deposit known as Margin. *Margin* is typically set at an amount that is larger than usual one-day moves in the futures price. This is done to ensure that both parties will have sufficient funds available to mark to market. Residual credit risk exists only to the extent that futures prices move so dramatically that the amount required to mark-to-market is larger than the balance of an individual's margin account, and the individual defaults on payment of the balance. In this case, the exchange bears the loss so that participants in futures markets bear essentially zero credit risk. Margin rules are stated in terms of *Initial margin* which must be posted when entering the contract and *Maintenance Margin* which is the minimum acceptable balance in the margin account. If the balance of the account falls below the maintenance level, the exchange makes a *Margin Call* upon the individual, who must then restore the account to the level of initial margin before the start of trading the following day.

i. Valuation of Future Contract

Whereas the valuation of forward contracts is relatively straightforward, the marking to market feature complicates the valuation of futures contracts. For both contracts, no money changes hands at the time the contract is initiated (time 0). For the forward contract, no money changes hand until the contract matures (time T). For the futures contract, money changes hands daily depending upon movements in the futures price.

In some circumstances, however, a futures contract is perfectly equivalent to a forward contract in which case the two contracts must have the same value. Since forward contracts are relatively easy to value using a no-arbitrage argument or break-even pricing, this provides a convenient way of valuing a futures contract. In particular, if interest rates are constant (at a continuously compounded annual rate of r) over the life of the contract then the prices of the futures contract and the forward contract are identical. The formula for the valuation of future contract therefore remains same, only difference is that carrying cost includes the margin maintenance cost as well. Therefore;

Future Contract Price = Spot Price of Asset X (Risk Free Return + Carrying Cost) ^ Delivery Time

$$F = S_0 \, e^{(q+r)T}$$

Where,

F = Price of Forward Contract
So = Spot Price of Underlying Asset (amount you need to invest now to purchase that asset)
q = Carrying Cost of Underlying Asset
r = Risk Free Rate of Return
T = Time to Delivery

The above is true as long as a forward contract has only a single payoff at maturity. However, if the underlying asset has a Dividend Payoff as well then, the formula changes as follows:

$$F = S_0 \, e^{(r-d)T}$$

This is the same as equation except that "+q" has been replaced by "-d" as the cost of carry has been replaced by a benefit i.e. dividends.

3. Market Swaps

A swap is an agreement between two parties to exchange cash flows for a set period of time. Usually, at the time the contract is initiated, at least one of these series of cash flows is determined by a random or uncertain variable, such as an interest rate, foreign exchange rate, equity price or commodity price. Conceptually, one may view a swap as either a portfolio of forward contracts, or as a long position in one bond coupled with a short position in another bond.

Unlike most standardized options and futures contracts, swaps are not exchange-traded instruments. Instead, swaps are customized contracts that are traded in the over-the-counter (OTC) market between private parties. Firms and financial institutions dominate the swaps market, with few individuals ever participating. Because swaps occur on the OTC market, there is always the risk of a counterparty defaulting on the swap.

The first-interest rate swap occurred between IBM and the World Bank in 1981. However, despite their relative youth, swaps have exploded in popularity.

The motivations for using swap contracts fall into two basic categories: commercial needs and comparative advantage. The normal business operations of some firms lead to certain types of interest rate or currency exposures that swaps can alleviate. For example, consider a bank, which pays a floating rate of interest on deposits i.e., liabilities and earns a fixed rate of interest on loans i.e., assets. This mismatch between assets and liabilities can cause tremendous difficulties. The bank could use a fixed-pay swap i.e. pay a fixed rate and receive a floating rate to convert its fixed-rate assets into floating-rate assets, which would match up well with its floating-rate liabilities.

Sometimes one of the swap parties needs to exit the swap prior to the agreed-upon termination date. This is similar to an investor selling an exchange-traded futures or option contract before expiration. There are four basic ways to do this.

- Buy Out the Counterparty
  Just like an option or futures contract, a swap has a calculable market value, so one party may terminate the contract by paying the other this market value. However, this is not an automatic feature, so either it must be specified in the swaps contract in advance, or the party who wants out must secure the counterparty's consent.

- Enter an Offsetting Swap
  For example, Company A from the interest rate swap example above could enter into a second swap, this time receiving a fixed rate and paying a floating rate.

- Sell the Swap to Someone Else
  Because swaps have calculable value, one party may sell the contract to a third party. As with Strategy 1, this requires the permission of the counterparty.

- Use a Swaption
  A swaption is an option on a swap. Purchasing a swaption would allow a party to set up, but not enter into, a potentially offsetting swap at the time they execute the original swap.

i. Equity Swap
An equity swap is a financial derivative contract where a set of future cash flows are agreed to be exchanged between two counterparties at set dates in the future. The two cash flows are usually referred to as "legs" of the swap; one of these "legs" is usually pegged to a floating rate such as LIBOR. This leg is also commonly referred to as the "floating leg". The other leg of the swap is based on the performance of either a share of stock or a stock market index. This leg is commonly referred to as the "equity leg". Most equity swaps involve a floating leg vs. an equity leg, although some exist with two equity legs. An equity swap involves a notional principal, a specified tenor and predetermined payment intervals.

In simple terms, an equity swap is a transaction in which one party agrees to make to the other a series of payments that are determined by the return on a stock or stock index. The other party, in turn, makes to the first party a series of payments that can be at a fixed rate, a floating rate or the return on another stock or index. An equity swap is designed to replicate the returns that would be earned from buying the stock, which could have been purchased by either selling other stock, borrowing at a fixed rate or borrowing at a floating rate. Alternatively, an equity swap can be used to remove exposure to a stock or index from a portfolio, replacing it with some other type of exposure.

Equity swaps differ in several ways from interest rate swaps. Since a stock return can be negative, the party receiving the return on the stock will have to pay the return on the stock when the stock goes down. Thus, in contrast to an interest rate swap where party A makes an interest payment to party B and party B makes an interest payment to party A, an equity swap can have one party making and one party receiving both payments. For both equity and interest rate swaps, however, the exchange of cash is usually done by netting the amounts owed, so there is only one cash amount transferred from one party to the other. Another way in which an equity swap differs from an interest rate swap is that, while the floating rate on an interest rate swap is typically set at the beginning of the settlement period, the return on the stock is not known until the end of the period, at which time settlement is made.

a. Valuation of Equity Swaps
In equity swaps with a fixed notional principal, counterparty pays the return on the equity index applied to a constant notional principal. To the other counterparty this specification is equivalent to a transaction in which it has invested in the equity index but withdraws the return each period, a process that could be described as periodic rebalancing to a constant dollar investment. With one party paying the equity return, the other party can pay a fixed return, a floating return or the return on another equity index. The formula to calculate the Equity Swap value is as follows:

Net Cash Flow of Equity Swap = PV of Floating Leg – PV of Equity Leg

Where,
Floating Leg = Amount x (LIBOR – Spread)
Equity Leg = Amount x (Dividends)

Let's assume you have a shares portfolio of $10 million at current market prices. The historic Dividend Yield of shares is 3%. You are exposed to 2 risks. Market value of your shares can go down and future dividends of your shares can be lower.

Equity Swap hedges only the risk of lower dividends. In order to hedge this risk, you enter into equity swap arrangement with an investment bank for one year. As per swap agreement you will pay your equity returns to bank and bank will pay you a floating return based on LIBOR. Therefore, in simple terms, you will pay bank any dividends that you receive from your share. Bank will pay you a return of LIBOR minus a Spread. Spread is a notional amount which is the difference between the LIBOR and Dividend Yield. Therefore, when you enter in a swap, the value of swap will be Zero.

Let's look at the data:

Current Market Value of Share =	$10 million
Historic Dividend Yield =	3%
LIBOR =	6%
Spread =	50%
Transaction Cost =	0%

Therefore, to start with:

Floating Leg = Amount x (LIBOR – Spread) is 10,000,000 x 6% (1 – 50%) or,
Floating Leg = 10,000,000 x 3% = 300,000

Similarly,
Equity Leg = Amount x Dividend Yield or,
Equity leg = 10,000,000 x 3% = 300,000

Net Cash Flow of Equity Swap = PV of Floating Leg – PV of Equity Leg or,
Net Cash Flow of Equity Swap = 300,000 – 300,000
Net Cash Flow of Equity Swap = 0

Let's assume after one year, dividend yield dropped to 2%. Now, floating leg calculations will be:

Floating Leg = Amount x (LIBOR – Spread) or,
Floating Leg = 10,000,000 x 6% (1 – 50%)
Floating Leg = 300,000
Floating Leg = 300,000

And equity leg calculations will be:
Equity Leg = Amount x (Dividends)
Equity Leg = 10,000,000 x (2%)
Equity Leg = 200,000
Equity Leg = 200,000

And since,
Net Cash Flow of Equity Swap = PV of Floating Leg – PV of Equity Leg
Net Cash Flow of Equity Swap = 300,000 – 200,000
Net Cash Flow of Equity Swap = 100,000

ii. Equity Default Swap
An equity default swap (EDS) is a form of OTC derivative. While technically an equity derivative, it behaves like a hybrid of a credit derivative and an equity derivative. The name "equity default swap" may seem peculiar—how can equity default? The answer is that the product is named by analogy with credit default swaps (CDSs), whose structures it mimics.

As with a credit default swap, an equity default swap is a vehicle for one party to provide another protection against some possible event relating to some reference asset. With a credit default swap, the reference asset is a debt instrument, and protection is provided against a possible default or other credit event. With an equity default swap, the reference asset is some company's stock, and protection is provided against a dramatic decline in the price of that stock. For example, the equity default swap might provide protection against a 70% decline in the stock price from its value when the equity default swap was initiated. The event being protected against is called the trigger event or knock-in event.

Other than the difference in the type of event being protected against, a credit default swap and equity default swap are structured identically. There are two parties to the agreement. Maturities are for several years, with five years being typical. The party buying protection pays the other a fixed periodic coupon for the life of the agreement. The other party makes no payments unless the trigger event occurs. If it does occur, the equity default swap terminates, and the protection seller makes a specified payment to the protection buyer. This is calculated as:

Notional Amount x (1 – Recovery Rate)

Where the notional amount is simply a dollar sum. In formula recovery rate serves only to make the equity default swap more analogous to a credit default swap. Its role is similar to the recovery rate that would be realized on a defaulted debt obligation. However, the recovery rate for an equity default swap is fixed—typically at 50%.

a. Valuation of Equity Default Swap
Equity Default Swap is same like Equity Swap and the only difference is that it covers both the dividends as well as market value of shares. Just like in equity swaps with a fixed notional principal, counterparty pays the return on the equity index applied to a constant notional principal. To the other counterparty this specification is equivalent to a transaction in which it has invested in the equity index but withdraws the return each period, a process that could be described as periodic rebalancing to a constant dollar investment. With one party paying the equity return, the other party can pay a fixed return, a floating return or the return on another equity index. The formula to calculate the Equity Swap value is as follows:

Net Cash Flow of Equity Swap = PV of Floating Leg – PV of Equity Leg

Where,
Floating Leg = Amount x (LIBOR – Spread) + Depreciation in Current Market Value of Shares
Equity Leg = Amount x (Dividends) + Appreciation in Current Market Value of Share

Let's assume you have a shares portfolio of $10 million at current market prices. The historic Dividend Yield of shares is 3%. You are exposed to 2 risks. Market value of your shares can go down and future dividends of your shares can be lower.

In order to hedge both of these risks, you enter into equity swap arrangement with an investment bank for one year. As per swap agreement you will pay your equity returns to bank and bank will pay you a floating return based on LIBOR. Therefore, in simple terms, you will pay bank any dividends that you receive from your share plus any appreciations in the market value of your shares. Bank will pay you a return of LIBOR minus a Spread and any depreciation in the market value of your shares. Spread is a notional amount which is the difference between the LIBOR and Dividend Yield. Therefore, when you enter in a swap, the value of swap will be Zero.

Let's look at the data:

Current Market Value of Share =	$10 million
Historic Dividend Yield =	3%
LIBOR =	6%
Spread =	50%
Transaction Cost =	0%

Therefore, to start with:

Floating Leg = Amount x (LIBOR – Spread) is 10,000,000 x 6% (1 – 50%) or,
Floating Leg = 10,000,000 x 3% = 300,000

Similarly,
Equity Leg = Amount x Dividend Yield or,
Equity leg = 10,000,000 x 3% = 300,000

Net Cash Flow of Equity Default Swap = PV of Floating Leg – PV of Equity Leg or,
Net Cash Flow of Equity Default Swap = 300,000 – 300,000
Net Cash Flow of Equity Default Swap = 0

Let's assume after one year, the market value of shares is dropped to $9 million and dividend yield during last year dropped to 2%. Now, floating leg calculations will be:

Floating Leg = Amount x (LIBOR – Spread) + Depreciation in Market Value of Shares or,
Floating Leg = 10,000,000 x 6% (1 – 50%) + 1,000,000
Floating Leg = 300,000 + 1,000,000
Floating Leg = 1,300,000

And equity leg calculations will be:
Equity Leg = Amount x (Dividends) + Appreciation in Current Market Value of Share
Equity Leg = 10,000,000 x (2%) + 0
Equity Leg = 200,000 + 0
Equity Leg = 200,000

And since,
Net Cash Flow of Equity Default Swap = PV of Floating Leg – PV of Equity Leg
Net Cash Flow of Equity Default Swap = 1,300,000 – 200,000
Net Cash Flow of Equity Default Swap = 1,200,000

4. Market Options
Option is a financial contract sold by one party called option writer to another party called option holder. The contract offers the buyer the right, but not the obligation, to buy (call) or sell (put) a security or other financial asset at an agreed-upon price called the strike price during a certain period of time or on a specific date called exercise date. Following are the basic definitions:

Option Writer: This refers to the party that sells the option.
Option Holder: This refers to the party that buys an option.
Strike Price: This refers to the price at which an asset is agreed to be bought or sold in a future date.
Exercise Date: This refers to the date at which option can be exercised.

Underlying Asset: This refers to the asset that can be bought or sold under the option contract.

There are two basic types of options i.e. Call Options and Put Options. *Call Options* give the option to buy at certain price, so the buyer would want the stock to go up. Put Options give the option to sell at a certain price, so the buyer would want the stock to go down.

The process of activating an option and thereby trading the underlying at the agreed-upon price is referred to as exercising it. If the option is not exercised by the expiration date, it becomes void and worthless.

In return for assuming the obligation, called writing the option, the originator of the option collects a payment, the premium, from the buyer. The writer of an option must make good on delivering or receiving the underlying asset or its cash equivalent, if the option is exercised. An option can usually be sold by its original buyer to another party. Many options are created in standardized form and traded on among the general public, these are called *Exchange Traded Options*. While other over-the-counter options are customized ad hoc to the desires of the buyer, usually by an investment bank, these are called *Over the Counter Options*.

There are 3 basic models for the valuation of options:

- Black Scholes Model
- Binomial Option Pricing Model
- Monte Carlo Option Model

The most popular method nowadays is Black Scholes Model.

i. Valuation of Option Value (Black Scholes)

In their 1973 paper, The Pricing of Options and Corporate Liabilities, Fischer Black and Myron Scholes published an option valuation formula that today is known as the Black-Scholes model. It has become the standard method of pricing options.

The Black-Scholes formula calculates the price of a Call Option to be:

$$C = S\ N(d_1) - K\ e^{-rT}\ N(d_2)$$

Where,

C = Price of the call option
S = Price of the underlying asset
K = Exercise price
r = Risk-free interest rate
T = Time until expiration
N () = Area under the normal curve

$$d_1 = \frac{\ln(\frac{S}{K}) + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(\frac{S}{K}) + (r - \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Similarly, the Black-Scholes formula calculates the price of a Put Option to be:

$$P = Ke^{-rT} N(-d_2) - S\, N(-d_1)$$

The Black-Scholes model assumes that the option can be exercised only at expiration. It requires that both the risk-free rate and the volatility of the underlying stock price remain constant over the period of analysis. The model also assumes that the underlying stock does not pay dividends; adjustments can be made to correct for such distributions. For example, the present value of estimated dividends can be deducted from the stock price in the model.

ii. Concept of Black Scholes Model

Black Scholes Model simply calculates a Risk Neutral value of an option. A *Risk Neutral* value is the break-even price of an option where both seller and buyer do not make any money therefore it is a fair value of an option. In order to understand Black Scholes calculations, let's assume you enter in an option that allows you to buy a share for $5 after 1 year. Current price of share is $4 in the market. Now whether you make money with this option or not will depend upon two things i.e. value of the cash that you receive when you exercise option and the value of the cash to buy the option. If value of cash that you receive when you exercise option is greater than the value of cash that you used to buy the option, then you have made money or else you have lost money. Therefore, simply speaking:

Value of Option = PV of Cash Received at Option Exercise – PV of Cash to Buy Option

a. PV of Cash to Buy Option

Firstly, if the option is exercised, we pay the strike price which is $5. We pay the strike price only if the underlying stock price is above the strike at maturity. So, to work out the expected value of this we need the probability simply that the stock price is above the strike at maturity. This probability is called N(d2), and the strike price is called K. Therefore, expected value of this is just KN(d2) at maturity. Since it is a future value, we need to discount it to calculate its present value. Discount factor is e ^-rt.

PV of Cash to Buy Option = $K\, e^{-rT}\, N(d_2)$

Where,

K =	Strike Price as per contract (Already Known)
T =	Time to Maturity of Option as per contract (Already Known)
r =	Discount Rate to calculate present value (Risk Free Rate, Already Known)
e =	Discounting Frequency (Continuous Discounting)
N(d2) =	Probability that Stock Price is greater than Strike Price

b. PV of Cash Received at Option Exercise

Secondly, if the option is exercised, we get a unit of the stock. This is clearly worth whatever the stock price is in the market at maturity. But this again only happens if the underlying stock price is above the strike at maturity.

It turns out that the expected value of this valued as at today is proportional to S, the stock price today, and can be written as SN(d1). That is to say, SN(d1) is the expected value of something that is equal to the final stock price if the final stock price is above the strike, and equal to zero if the final stock price is below the strike.

PV of Cash Received at Option Exercise = $S\ N(d_1)$

Where,

S = Current Spot Price

N(d1) = Expected Value of the difference between Strike Price and Spot Price in Future.

Therefore, the complete formula is as under:

$$C = S\ N(d_1) - K\ e^{-rT}\ N(d_2)$$

The values of d1 and d2 depend upon the volatility of stock. Technically volatility is defined as the annualized standard deviation of the return on an asset. They are expressed as percentages. In order to calculate the expected value of our option we would consider a series of distinct values of the price of the stock at maturity. Black Scholes method assumes that the stock price can take any value continuously between minus infinity and plus infinity at maturity.

Why does volatility affect the price of an option? Again, this is because our payoff graph is not symmetrical. A stock that has a high volatility is more likely to swing around, and hence more likely to have a very high value or very low value at maturity. A stock with a low volatility is more likely to be close to its current value at maturity.

Now if the stock price at maturity is below our strike price we don't care if it's just slightly below or massively below. In both cases we don't exercise the option and don't make any money.

But if the share price at maturity is above our strike, we really want it to be as far above the strike as is possible, since we make more money the higher the volume is.

So, an option with a high volatility is more likely to make us lots of money if the price goes up, but won't lose us lots of money even if the price goes down hugely. As a result, options with high volatility are more valuable than options with low volatility.

iii. Valuation of Change in Option Value (Ito's Lemma)

The theoretical value of an option is evaluated according to any of several mathematical models. These models, which are developed by quantitative analysts, attempt to predict how the value of an option changes in response to changing conditions. For example, how the price changes with respect to changes in time to expiration or how an increase in volatility would have an impact on the value.

The value of an option is calculated on the basis of break-even price just like forwards and future. *Break Even Price* refers to a price on which, neither the seller nor the buyer will either earn or lose any money. In general value of any option is dependent upon following 5 factors:

- Spot Price: The current market price of the underlying asset.
- Strike Price: The strike price of the underlying asset under option.
- Carrying Cost: The cost of holding a position in the underlying asset, including interest and dividends.
- Expiry Date: The time to expiration together with any restrictions on when exercise may occur.

- Volatility: An estimate of the future volatility of the underlying asset's price over the life of the option.

Any changes in the above factors will change the value of an option. Therefore, change in the value of an option can be calculated by using *Greeks Values* which represent % changes in option value due to changes in the above factors. In line with these factors, following Greeks will be used:

Delta Δ: Change in the value of an option due to change in Spot Price.
Theta θ: Change in the value of an option due to change in days left in Expiry Date.
Vega *v*: Change in the value of an option due to change in Volatility.
Gamma Γ: Change in the value of Delta due to change in Spot Price.

Therefore, the change in the value of an option will be calculated by adding the impact of changes in these Greeks:

Change in Value = (Delta x Change in Spot Price) + (Theta x Change in Time) + (Vega x Change in Volatility) + (Gamma x Change in Delta)

Let's assume the following representations:

Spot Price =	S
Change =	d
Change in Spot Price =	dS
Change in Call Option Value =	dC
Change in the value of option due to change in Spot Price (Delta) =	Δd
Change in the value of option due to change in days left in Expiry Date (Theta) =	θd
Change in the value of option due to change in Volatility (Vega) =	vd
Change in the value of option due to change in Delta (Gamma) =	Γd

Therefore,

dC = ΔdS + Γ(dS^2/2) + vd + θd

Let's do a calculation based on hypothetical scenario to understand how this formula works. Assume the value of a call option is $1.89. This option is expiring after 99 days. The strike price of option is $50 for a share that has a spot price of $48 today. The delta, gamma, vega and theta of option are 0.439, 0.0631, 9.6, and −0.022 respectively. The volatility of share is 25%.

Assume that next day the spot price changes to $48.5 and volatility changes to 23.5%. What will be the change in the value of the option? And what will be the new price of option?

In order to solve this problem, let's first classify the data:

Change in Spot Price (dS) =	$0.5	($48.5 - $48)
Change in Volatility (dv) =	-0.015	(23.5% - 25%)
Change in Time (dθ) =	1 Day	
Delta =	0.439	
Gamma =	0.0631	
Vega =	9.6	
Theta =	-0.022	

Since,

dC = ΔdS + Γ(dS^2/2) + vd + θd

Therefore,

dC = (0.439 x 0.5) + (0.0631 x 0.5^2/2) + (9.6 x -0.015) + (-0.022 x 1)
dC = 0.0416

Therefore, change in value of option is + $0.0416 and the new value of option will be $1.9514 ($1.89 + $0.0416)

iv. Types of Options
Naming conventions are used to help identify properties common to many different types of options. These include:

- European Option: An option that may only be exercised on expiration.
- American Option: An option that may be exercised on any trading day on or before expiry.
- Bermudan Option: An option that may be exercised only on specified dates on or before expiration.
- Barrier Option: Any option with the general characteristic that the underlying security's price must pass a certain level or "barrier" before it can be exercised.
- Exotic Option: Any of a broad category of options that may include complex financial structures.
- Vanilla Option: Any option that is not exotic.

Examples of Exotic Options:
Given below are the definitions of selected exotic options. The payoffs of these options are calculated quite differently. Although these instruments are far more unusual, they can also vary in exercise style at least theoretically between European and American:

- *Look Back Option* is a path dependent option where the option owner has the right to buy (sell) the underlying instrument at its lowest (highest) price over some preceding period.

- *Asian Option or Average Option* is an option where the payoff is not determined by the underlying price at maturity but by the average underlying price over some pre-set period of time.

- *Russian Option* is a look back option which runs for perpetuity. That is, there is no end to the period into which the owner can look back.

- *Game Option or Israeli Option* is an option where the writer has the opportunity to cancel the option he has offered, but must pay the payoff at that point plus a penalty fee.

- *Cumulative Parisian Option* is dependent on the total amount of time the underlying asset value has spent above or below a strike price.

- *Standard Parisian Option* is dependent on the maximum amount of time the underlying asset value has spent consecutively above or below a strike price.

- *Barrier Option* involves a mechanism where if a 'limit price' is crossed by the underlying, the option either can be exercised or can no longer be exercised.

- *Double Barrier Option* involves a mechanism where if either of two 'limit prices' is crossed by the underlying, the option either can be exercised or can no longer be exercised.

- *Cumulative Parisian Barrier Option* involves a mechanism where if the total amount of time the underlying asset value has spent above or below a 'limit price', the option can be exercised or can no longer be exercised.

- *Standard Parisian Barrier Option* involves a mechanism where if the maximum amount of time the underlying asset value has spent consecutively above or below a 'limit price', the option can be exercised or can no longer be exercised.

- *Re-option* occurs when a contract has expired without having been exercised. The owner of the underlying security may then re-option the security.

- *Binary Option* also known as a digital option pays a fixed amount or nothing at all, depending on the price of the underlying instrument at maturity.

- *Chooser Option* gives the purchaser a fixed period of time to decide whether the derivative will be a vanilla call or put.

- *Forward Start Option* is an option whose strike price is determined in the future.

5. Market Sawptions

A Swaption is an option granting its owner the right but not the obligation to enter into an underlying swap. Although options can be traded on a variety of swaps, the term "Swaption" typically refers to options on interest rate swaps and has limited application in equities risk management.

There are two types of Swaption contracts:

- A Payer Swaption gives the owner of the Swaption the right to enter into a swap where they pay the fixed leg and receive the floating leg.
- A receiver Swaption gives the owner of the Swaption the right to enter into a swap in which they will receive the fixed leg, and pay the floating leg.

The buyer and seller of the Swaption agree on:

- Premium (price) of the Swaption
- Strike Rate (equal to the fixed rate of the underlying swap)
- Length of the Option Period (which usually ends two business days prior to the start date of the underlying swap)
- Terms of the underlying swap
- Notional Amount
- Frequency of Settlement of Payments on the Underlying Swap = Basis Point Spread
- Amortization (If applicable)

From the point of view of the payer, Swaptions increase in value with the volatility of the underlying swap rate, with curve steepness, and with the absolute level of the rate curve. For the receiver, the opposite is true. As with any other option, if the Swaption is not exercised by maturity, it expires worthless.

There are three main categories of Swaption, although exotic desks may be willing to create customized types, analogous to exotic options, in some cases. The standard varieties are:

- Bermudan Swaption: The owner is allowed to enter the swap on multiple specified dates.
- European Swaption: The owner is allowed to enter the swap only on the maturity date.
- American Swaption: The owner is allowed to enter the swap on any day that falls within a range of two dates.

i. Valuation of Swaptions

The valuation of Swaptions is complicated in that the at-the-money level is the forward swap rate, being the forward rate that would apply between the maturity of the option - time m - and the tenor of the underlying swap such that the swap, at time m, would have an "NPV" of zero. Moneyness, therefore, is determined based on whether the strike rate is higher, lower, or at the same level as the forward swap rate.

A regular Swaption valuation is a straightforward use of Black formula as payoff translates to:

Payoff = Constant * Max (Forward Rate - Strike Rate, 0)
Volatility being quoted as volatility of Forward Rate

CREDIT RISK

(Theory, Calculations and Practical Concepts)

I. Definition of Credit Risk

Credit risk is an investor's risk of loss arising from a borrower who does not make payments as promised. Such an event is called a *Default*. Another term for credit risk is *Default Risk*. In simple terms credit risk is the risk of loss of principal or loss of a financial reward stemming from a borrower's failure to repay a loan or otherwise meet a contractual obligation. Credit risk arises whenever a borrower is expecting to use future cash flows to pay a current debt. Investors are compensated for assuming credit risk by way of interest payments from the borrower or issuer of a debt obligation.

Credit risk is closely tied to the potential return of an investment, the most notable being that the yields on bonds correlate strongly to their perceived credit risk. The higher the perceived credit risk, the higher the rate of interest that investors will demand for lending their capital. Credit risks are calculated based on the borrowers' overall ability to repay. This calculation includes the borrowers' collateral assets, revenue-generating ability and taxing authority such as for government and municipal bonds.

Credit risks are a vital component of fixed-income investing, which is why ratings agencies such as S&P, Moody's and Fitch evaluate the credit risks of thousands of corporate issuers and municipalities on an ongoing basis. Credit risk is basically divided into 3 categories namely *Default Risk*, *Credit Spread Risk* and *Downgrade Risk*.

1. Default Risk

Default Risk is the risk of the event in which companies or individuals will be unable to make the required payments on their debt obligations. Lenders and investors are exposed to default risk in virtually all forms of credit extensions. To mitigate the impact of default risk, lenders often charge rates of return that correspond the debtor's level of default risk. The higher the risk, the higher the required return, and vice versa.

2. Credit Spread Risk

The difference between the yield on a corporate bond and a government bond is called the Credit Spread. As government bonds are considered Risk Free, while corporate bonds have a default risk arising from several factors, therefore corporate bonds offer more interest returns as compared to government bonds. The payoff for assuming all these extra risks is a higher yield. Credit Spread Risk refers to the mismatch between risks undertaken and potential returns for these risks. In simple terms it is the risk that you undertake higher risks while being compensated at a return which is not as high as it should be.

3. Downgrade Risk

Downgrade risk is the risk that a bond price will decline due to a downgrade in its credit rating. Credit ratings, assigned by agencies such as Moody's or S&P, are indicators of default risk (the possibility that the issuer cannot pay the bondholder) on a particular bond. Lower ratings suggest that a bond issue is riskier than an issue with higher ratings, which in turn leads to a lower price. A downgrade, therefore leads to a lower price.

The downgrade risk arises from deteriorating financial condition of a company, and every bond faces this risk to a certain extent.

II. Measurement of Credit Risk - (Credit Risk Metrics)

Credit risk is measured by various different measurement methodologies representing different metrics, yet the macro framework remains same. Regardless of approach, following 3 parameters need to be calculated in order to accurately measure credit risk.

There are basically 3 types of Credit Risk Models which are described below:

a. Structural Models
These models take Balance Sheet Approach and calculate risk metrics from the balance sheet of the firm.

b. Empirical Models
These models calculate risk metrics in relation to bench mark companies which have defaulted in past. These types of models simply compare firm's data with bench marked defaulted companies and tries to calculate credit risks.

c. Reduced Form Models
These models analyze external signals to calculate defaults and credit risks. External signals include analysis of macro-economic indicators, industry indicators, credit ratings etc.

The basic method of credit risk calculation is a 3-step process:

- Analyze credit risk of counter party using any of the above models.
- Map risk grade with associated Probability of Default.
- Calculate facility specific Probability of Default.

1. Exposure at Default – EAD
Exposure at Default is the total amount that a lender will lose in case of a default from the counter party. EAD is equal to the total outstanding amount of loan shown in balance sheet. Elaborately, EAD can be seen as an estimation of the extent to which a bank may be exposed to counterparty in the event of, and at the time of, that counterparty's default. It is a measure of potential exposure in currency as calculated by a Basel Credit Risk Model for the period of 1 year or until maturity whichever is sooner. Based on Basel Guidelines, Exposure at Default (EAD) for loan commitments measures the amount of the facility that is likely to be drawn if a default occurs.

EAD is calculated for both on balance sheet and off-balance sheet exposures. For on balance sheet exposures, EAD is equal to the nominal amount shown on balance sheet without taking account of guarantees, collateral or security which means it ignores Credit Risk Mitigation Techniques with the exception of on-balance sheet netting where the effect of netting is included. *Netting* refers to the net exposure resulting from account receivables and account payables of and from the same counter party.

Off balance sheet items include two things i.e. transactions with uncertain future drawdown, such as commitments and revolving credits, and OTC foreign exchange, interest rate and equity derivative contracts.

All estimates of EAD should be calculated net of any specific provisions a bank has already booked in its PNL against an exposure.

Therefore, in terms of calculations:

EAD = On Balance Sheet Loans + Off Balance Sheet Potential Exposures – Provisions Already Taken in PNL

Where, on balance sheet loans are taken as net exposure from a certain party i.e. difference between receivable and payable from same party.

As per Basel Accord II, EAD is calculated under 2 approaches i.e. *Foundation Internal Rating Based Approach* and *Advanced Internal Rating Based Approach*.

i. Calculation of EAD under Foundation Internal Rating Based Approach (FIRB)
Under F-IRB EAD is calculated taking account of the underlying asset, forward valuation, facility type and commitment details. This value does not take account of guarantees, collateral or security (i.e. ignores Credit Risk Mitigation Techniques with the exception of on-balance sheet netting where the effect of netting is included in Exposure at Default. For on-balance sheet transactions, EAD is identical to the nominal amount of exposure. On-balance sheet netting of loans and deposits of a bank to a corporate counterparty is permitted to reduce the estimate of EAD under certain conditions. For off-balance sheet items, there are two broad types which the IRB approach needs to address: transactions with uncertain future drawdown, such as commitments and revolving credits, and OTC foreign exchange, interest rate and equity derivative contracts.

ii. Calculation of EAD under Advanced Internal Rating Based Approach (AIRB)
Under A-IRB, the bank itself determines the appropriate EAD to be applied to each exposure. A bank using internal EAD estimates for capital purposes might be able to differentiate EAD values on the basis of a wider set of transaction characteristics (e.g. product type) as well as borrower characteristics. These values would be expected to represent a conservative view of long-run averages, although banks would be free to use more conservative estimates. A bank wishing to use its own estimates of EAD will need to demonstrate to its supervisor that it can meet additional minimum requirements pertinent to the integrity and reliability of these estimates. All estimates of EAD should be calculated net of any specific provisions a bank may have raised against an exposure.

In terms of assigning estimates of EAD to broad EAD classifications, banks may use either internal or external data sources. Given the perceived current data limitations in respect of EAD (in particular external sources) a minimum data requirement of 7 years has been set.

2. Probability of Default – PD
The probability of default (also call Expected Default Frequency) is the likelihood that a loan will not be repaid and will fall into default. PD is calculated for each client who has a loan for wholesale banking or for a portfolio of clients with similar attributes for retail banking. The credit history of the counterparty / portfolio and nature of the investment are taken into account to calculate the PD.

There are many alternatives for estimating the probability of default. Default probabilities may be estimated from a historical data base of actual defaults using modern techniques like logistic regression. Default probabilities may also be estimated from the observable prices of credit default swaps, bonds, and options on common stock. The simplest approach, taken by many banks, is to use external ratings agencies such as Standard and Poors, Fitch or Moody's Investors Service for estimating PDs from historical default experience. For small business default probability estimation, logistic regression is again the most common technique for estimating the drivers of default for a small business based on a historical data base of defaults. These models are both developed internally and supplied by third parties. A similar approach is taken to retail default, using the term "credit score" as a euphemism for the default probability which is the true focus of the lender.

Calculation of probability of default requires the following simple steps:

- Analyze the credit risk aspects of the counterparty / portfolio through ratings or credit scores.
- Map the counterparty to an internal risk grade which has an associated PD.
- Determine the facility specific PD. This last step will give a weighted Probability of Default for facilities that are subject to a guarantee or protected by a credit derivative. The weighting takes account of the PD of the guarantor or seller of the credit derivative.

As per Basel Accord II, PD is calculated under 3 approaches i.e. *Standardized Approach*, *Foundation Internal Rating Based Approach* and *Advanced Internal Rating Based Approach*.

i. Calculation of PD under Standardized Approach
The term Standardized Approach refers to a set of credit risk measurement techniques proposed under Basel II rules for lending institutions. Under this approach the lending institutions are required to use ratings from External Credit Rating Agencies to quantify probability of default. In many countries this is the only approach the regulators are planning to approve in the initial phase of Basel II Implementation.

There are some options in weighting risks for some claims, below are the summary as it might be likely to be implemented.

CORPORATE RISK WEIGHTAGES IN STANDARDIZED APPROACH

CREDIT ASSESSMENT	AAA TO AA-	A+ TO A-	BBB+ TO BBB-	BB+ TO B-	BELOW BB-	BELOW B-	UNRATED
Soverign Risk Weight	0%	20%	50%	100%	150%	150%	100%
Bank Risk Weight	20%	50%	100%	100%	150%	150%	100%
Corporate Risk Weight	20%	50%	100%	150%	150%	150%	100%

CORPORATE RISK WEIGHTAGES IN STANDARDIZED APPROACH

CREDIT ASSESSMENT	RISK WEIGHTAGE
Retail Products	75%
Residential Property	35%
Commercial Property	100%
All Other Assets	100%

RISK WEIGHTAGES FOR OVER DUE LOANS

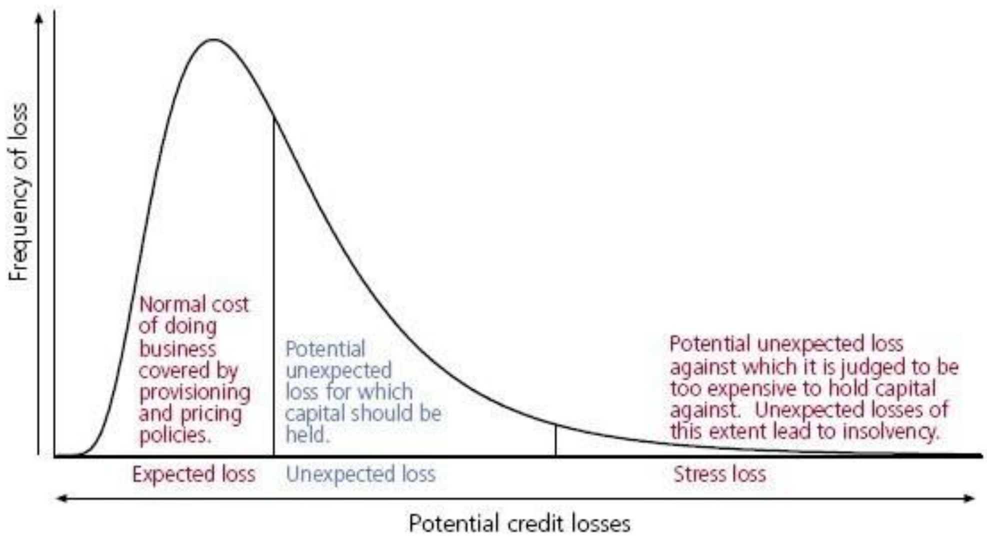
CREDIT ASSESSMENT	RISK WEIGHTAGES
Outstanding Amount < 20%	150%
Outstanding Amount between 20% - 49%	100%
Outstanding Amount > 49%	100%

ii. Calculation of PD under Foundation Internal Rating Based Approach (FIRB)
The term Foundation IRB or F-IRB is an abbreviation of foundation internal ratings-based approach and it refers to a set of credit risk measurement techniques proposed under Basel II capital adequacy rules for banking institutions.

Under this approach the banks are allowed to develop their own empirical model to estimate the PD (probability of default) for individual clients or groups of clients. Banks can use this approach only subject to approval from their local regulators.

Some credit assessments in standardized approach refer to unrated assessment. Basel II also encourages banks to initiate internal-ratings based approach for measuring credit risks. Banks are expected to be more capable of adopting more sophisticated techniques in credit risk management.

Banks can determine their own estimation for some components of risk measure: the probability of default (PD), exposure at default (EAD) and effective maturity (M). The goal is to define risk weights by determining the cut-off points between and within areas of the expected loss (EL) and the unexpected loss (UL), where the regulatory capital should be held, in the probability of default. Then, the risk weights for individual exposures are calculated based on the function provided by Basel II.



iii. Calculation of PD under Advanced Internal Rating Based Approach (AIRB)
The term Advanced IRB or A-IRB is an abbreviation of advanced internal rating-based approach and it refers to a set of credit risk measurement techniques proposed under Basel II capital adequacy rules for banking institutions.

Under this approach the banks are allowed to develop their own empirical model to quantify required capital for credit risk. Banks can use this approach only subject to approval from their local regulators.

Under A-IRB banks are supposed to use their own quantitative models to estimate PD (probability of default), EAD (Exposure at Default), LGD (Loss Given Default) and other parameters required for calculating the RWA (Risk Weighted Asset). Then total required capital is calculated as a fixed percentage of the estimated RWA.

3. Loss Given Default – LGD
LGD is the credit loss incurred if an obligor defaults. Loss Given Default is facility-specific because such losses are generally understood to be influenced by key transaction characteristics such as the presence of collateral and the degree of subordination. Therefore, the difference between EAD and LGD is that EAD ignores the value of collateral and guarantees while LGD is calculated net of collaterals and guarantees.

In order to understand the calculation of LGD, it is important to first understand the 3 types of losses that are added to calculate LGD. These 3 types of losses are known as *Book Value Loss*, *Interest Loss* and *Workout Costs*.

Book Value Loss refers to the loss of value in balance sheet due to write -off. Book value losses can also arise in the course of restructuring due to a partial write-off or in the course of liquidation. The liquidation itself can be based on bankruptcy realization or the realization of collateral. Simply speaking Book Value Loss is the value of loan that a lender will not be able to recover by selling collaterals in case of a default.

Interest Loss refers to the interest payment streams lost due to the default. As a rule, the agreed interest rate implicitly includes refinancing costs, process and overhead costs, premiums for expected and unexpected loss, as well as the calculated profit. The present value calculated by discounting the interest payment stream with the risk-free term structure of interest rates represents the realized interest loss.

Workout Costs refers to the total additional costs that need to be incurred in order to sell the collateral. This includes restructuring costs, legal costs, valuation costs, selling costs and commissions etc.

LGD is calculated as a Percentage and LGD percentage is multiplied by EAD to calculate the amount of loss. Mathematically speaking:

LGD Amount = % LGD X EAD

% LGD is calculated by two popular methods i.e. *Gross LGD* and *Balnco LGD*.

Gross LGD is calculated by dividing Total Estimated Losses by EAD while *Blanco LGD* is calculated by Total Estimated Losses of Unsecured Debts by EAD. If collateral value is zero in the last case, then Blanco LGD is equivalent to Gross LGD. Different types of statistical methods can be used to do this.

Gross LGD is most popular amongst academics because of its simplicity and because academics only have access to bond market data, where collateral values often are unknown, uncalculated or irrelevant. Blanco LGD is popular amongst some practitioners (banks) because banks often have many secured facilities, and banks would like to decompose their losses between losses on unsecured portions and losses on secured portions due to depreciation of collateral quality. The latter calculation is also a subtle requirement of Basel II, but most banks are not sophisticated enough at this time to make those types of calculations.

As per Basel II, LGD is calculated under 3 approaches i.e. *Standardized Approach*, *Foundation Internal Rating Based Approach* and *Advanced Internal Rating Based Approach*.

i. Calculation of LGD under Standardized Approach

Under Standardized Approach, LGD is calculated separately for collateral-based exposures and exposures without collateral.

a. LGD for Exposure without Collateral

Under the foundation approach, BIS prescribes fixed LGD ratios for certain classes of unsecured exposures:

- Senior claims on corporates, sovereigns and banks not secured by recognized collateral attract a 45% LGD.
- All subordinated claims on corporates, sovereigns and banks attract a 75% LGD.

b. LGD for Exposure with Collateral

The effective loss given default (LGD) applicable to a collateralized transaction can be expressed as:

% LGD = LGD X (E* / E)

Where,

LGD is that of the senior unsecured exposure before recognition of collateral (45%).

E is the current value of the exposure (i.e. cash lent or securities lent or posted).

E* should be calculated based on the following formula:

$$E^* = \max \{0, [E \times (1 + He) - C \times (1 - Hc - Hfx)]\}$$

Where,

E* = the exposure value after risk mitigation

E = current value of the exposure

He = haircut appropriate to the exposure

C = the current value of the collateral received

Hc = haircut appropriate to the collateral

Hfx = haircut appropriate for currency mismatch between the collateral and exposure (The standard supervisory haircut for currency risk where exposure and collateral are denominated in different currencies is 8%)

The *He and *Hc has to be derived from the following table of standard supervisory haircuts:

Issue rating for debt securities	Residual Maturity	Sovereigns	Other issuers
AAA to AA-/A-1	≤ 1 year	0.5	1
	>1 year, ≤ 5 years	2	4
	> 5 years	4	8
A+ to BBB-/ A-2/A-3/P-3 and unrated bank securities per para. 145(d)	≤ 1 year	1	2
	>1 year, ≤ 5 years	3	6
	> 5 years	6	12
BB+ to BB-	All	15	
Main index equities (including convertible bonds) and Gold		15	
Other equities (including convertible bonds) listed on a recognised exchange		25	
UCITS/Mutual funds		Highest haircut applicable to any security in which the fund can invest	
Cash in the same currency		0	

ii. Calculation of LGD under Foundation & Advanced Internal Rating Based Approach

Under the A-IRB approach and for the retail-portfolio under the F-IRB approach, the bank itself determines the appropriate Loss given default to be applied to each exposure, on the basis of robust data and analysis. The analysis must be capable of being validated both internally and by supervisors. Thus, a bank using internal Loss Given Default estimates for capital purposes might be able to differentiate Loss Given Default values on the basis of a wider set of transaction characteristics (e.g. product type, wider range of collateral types) as well as borrower characteristics. These values would be expected to represent a conservative view of long-run averages. A bank wishing to use its own estimates of LGD will need to demonstrate to its supervisor that it can meet additional minimum requirements pertinent to the integrity and reliability of these estimates.

a. Downturn LGD

Under Basel II, banks and other financial institutions are recommended to calculate 'Downturn LGD' (Downturn Loss Given Default), which reflects the losses occurring during a 'Downturn' in a business cycle for regulatory purposes. Downturn LGD is interpreted in many ways, and most financial institutions that are applying for IRB approval under BIS II often have differing definitions of what Downturn conditions are. One definition is at least two consecutive quarters of negative growth in real GDP. Often, negative growth is also accompanied by a negative output gap in an economy (where potential production exceeds actual demand).

The calculation of LGD (or Downturn LGD) poses significant challenges to modelers and practitioners. Final resolutions of defaults can take many years and final losses, and hence final LGD, cannot be calculated until all of this information is ripe. Furthermore, practitioners are of want of data since BIS II implementation is rather new and financial institutions may have only just started collecting the information necessary for calculating the individual elements that LGD is composed of: EAD, direct and indirect Losses, security values and potential, expected future recoveries. Another challenge, and maybe the most significant, is the fact that the default definitions between institutions vary. This often results in a so-called differing cure-rates or percentage of defaults without losses. Calculation of LGD (average) is often composed of defaults with losses and defaults without. Naturally, when more defaults without losses are added to a sample pool of observations LGD becomes lower. This is often the case when default definitions become more 'sensitive' to credit deterioration or 'early' signs of defaults. When institutions use different definitions, LGD parameters therefore become non-comparable.

Many institutions are scrambling to produce estimates of Downturn LGD, but often resort to 'mapping' since Downturn data is often lacking. Mapping is the process of guesstimating losses under a downturn by taking existing LGD and adding a supplement or buffer, which is supposed to represent a potential increase in LGD when Downturn occurs. LGD often decreases for some segments during Downturn since there is a relatively larger increase of defaults that result in higher cure-rates; often the result of temporary credit deterioration that disappears after the Downturn Period is over. Furthermore, LGD values decrease for defaulting financial institutions under economic Downturns because governments and central banks often rescue these institutions in order to maintain financial stability.

III. Credit Risk Models

There are two primary types of models that attempt to describe default processes in the credit risk literature:

- Structural Models.
- Reduced Form Models.

1. Structural Models

Structural Models use the evolution of firms' structural variables, such as asset and debt values, to determine the time of default. Merton's model (1974) was the first modern model of default and is considered the first structural model. In Merton's model, a firm defaults if, at the time of servicing the debt, its assets are below its outstanding debt. A second approach, within the structural framework, was introduced by Black and Cox (1976). In this approach defaults occur as soon as firm's asset value falls below a certain threshold. In contrast to the Merton approach, default can occur at any time.

2. Reduced Form Models

Reduced Form Models do not consider the relation between default and firm value in an explicit manner. In contrast to structural models, the time of default in intensity models is not determined via the value of the firm, but it is the first jump of an exogenously given jump process. The parameters governing the default hazard rate are inferred from market data.

Structural default models provide a link between the credit quality of a firm and the firm's economic and financial conditions. Thus, defaults are endogenously generated within the model instead of exogenously given as in the reduced approach. Another difference between the two approaches refers to the treatment of recovery rates: whereas reduced models exogenously specify recovery rates, in structural models the value of the firm's assets and liabilities at default will determine recovery rates.

IV. Popular Credit Risk Models

1. Merton Model

The Merton model is a model proposed by Robert C. Merton in 1974 for assessing the credit risk of a company by characterizing the company's equity as a call option on its assets. Put-call parity is then used to price the value of a put and this is treated as an analogous representation of the firm's credit risk.

This model assumes that a company has a certain amount of zero-coupon debt that will become due at a future time T. The company defaults if the value of its assets is less than the promised debt repayment at time T. The equity of the company is a European call option on the assets of the company with maturity T and a strike price equal to the face value of the debt. The model can be used to estimate either the risk-neutral probability that the company will default or the credit spread on the debt.

The model takes three company specific inputs: the equity spot price, the equity volatility (which is transformed into asset volatility), and the debt/share. The model also takes two inputs which should be calibrated to market quoted CDS spreads: the default barrier, and the volatility of the default barrier. These inputs are used to specify a diffusion process for the asset value. The entity is deemed to have defaulted when the asset value drops below the barrier. The barrier itself is stochastic, which has the effect of incorporating jump-to-default risk into the model. The Merton model evolves asset value movements through a diffusion process and a fundamental purpose of the default barrier volatility is to provide a jump-like process which can capture short term default probabilities.

The Merton model has been shown to be empirically accurate for non-financial firms, especially manufacturing entities. The highly leveraged nature of financial firms produces CDS spreads which are significantly higher than observed in the market due to the asset diffusion process.

Merton's model has been extended in a number of ways. For example, one version of the model assumes that a default occurs whenever the value of the assets falls below a barrier level.

i. Structure of Merton Model
The model considers a corporation financed through a single debt and a single equity issue. The debt comprises a zero-coupon bond that matures at time t = t*, at which time it is to pay investors b dollars. The equity pays no dividends.

An unobservable process V describes the firm's value tV >= 0 at any time t. We ascribe the outstanding debt and equity values and respectively. Accordingly, at any time:

tV = tF + tE

At time t*, the firm's debt matures. At that time, either will exceed the bond's maturity value b, or it won't. In the former case, the firm will pay off the bondholders. The remaining value of the firm will belong to the equity holders, so

t*E = t*V – b

In the latter case, the firm defaults on its debt. The bondholders take ownership of the firm, and the stockholders are left with nothing:

t*E = 0

Combining the above two results, we obtain a general expression for the value of the firm's stock at the maturity of its debt:

t*E = max (t*V – b, 0)

Look closely at this formula. It is precisely the payoff of a call option on the firm's value t*V with strike price b. Based upon this realization; the asset value model treats the firm's equity as a call option on the value of the firm struck at the maturity value b of its debt. By put-call parity, the firm's debt comprises a risk-free bond that guarantees payment of b plus a short put option on the value of the firm struck at b. Accordingly:

t*F = b – max (b – t*V, 0)

The asset value model treats t*V just like any underlier. It assumes t*V follows a geometric Brownian motion with volatility. Further, it makes all the other simplifying assumptions of the Black-Scholes (1973) option pricing formula. Accordingly, the firm's equity can be valued at any time t as:

tE = c (tV, b, σ, r, t* - t)

Where c is the Black-Scholes formula for the value of a call option, and r is the risk-free rate. By this, we can similarly value the firm's debt as:

tF = be^-rt – p (tV, b, σ, r, t* - t)

Where, p is the Black-Scholes formula for the value of a put. Note that we discount the payment b at the risk-free rate because that payment is risk-free in formula. We have stripped out the credit risk as a put option.

At any time t, the distance to default for the firm's debt is defined as:

(tV – b) / σ

This is a metric indicating how many standard deviations the equity holders' call option is in-the-money. The smaller the distance to default, the more likely a default is to occur. The probability of default is precisely the probability of the call option expiring out-of-the-money. This is approximately equal to one minus the option's normalized delta if investors were risk neutral, equality would be exact.

Three shortcomings of the asset value model are:

- Its assumption that the firm's debt financing consists of a one-year zero-coupon bond is, for most firms, an oversimplification.
- The Black-Scholes (1973) simplifying assumptions are questionable in the context of corporate debt, and
- The firm's value tV is not observable, which makes assigning values to it and its volatility problematic.

Still, the model provides a useful context for considering and modeling credit risk. Practical implementations of the model are used by financial institutions and institutional investors.

2. Jarrow Turnbull Model – KMV Model

The Jarrow–Turnbull credit risk model was published by Robert A. Jarrow of Kamakura Corporation and Cornell University and Stuart Turnbull, currently at the University of Houston. Many experts in financial theory label the Jarrow–Turnbull model as the first "reduced-form" credit model. Reduced-form models are an approach to credit risk modeling that contrasts sharply with the "structural credit models". The structural or "Merton" credit models are single-period models which derive the default probability from the random variation in the unobservable value of the firm's assets. Two years after the development of the structural credit model, Robert Merton modeled bankruptcy as a continuous probability of default. Upon the random occurrence of default, the stock price of the defaulting company is assumed to go to zero. Merton derived the value of options for a company that can default. This was in fact the first "reduced form" model where bankruptcy is modeled as a statistical process, rather than as a microeconomic model of the firm's capital structure.

The Jarrow–Turnbull model extends the reduced-form model of Merton (1976) to a random interest rates framework. Large financial institutions employ default models of both the structural and reduced form types. The Merton structural default probabilities were first offered by KMV LLC in the early 1990s. KMV LLC was acquired by Moody's Investors Service in 2002. Kamakura Corporation, where Robert Jarrow serves as director of research, has offered both structural and reduced form default probabilities on public companies since 2002.

KMV model is based on the structural approach to calculate EDF (credit risk is driven by the firm value process). Expected default frequency (EDF) is a forward-looking measure of actual probability of default. EDF is firm specific. It is best when applied to publicly traded companies, where the value of equity is determined by the stock market. The market information contained in the firm’s stock price and balance sheet are translated into an implied risk of default. According to KMV’s empirical studies, log-asset returns confirm quite well to a normal distribution, and σV stays relatively constant.

There are three steps to derive the actual probabilities of default:

- Estimation of the market value and volatility of the firm's asset.
- Calculation of the distance to default, an index measure of default risk.
- Scaling of the distance to default to actual probabilities of default using a default database.

i. Estimation of Firm Value V and Volatility of Firm Value σV

- Usually, only the price of equity for most public firms is directly observable, and in some cases, part of the debt is directly traded.
- Using option pricing approach: equity value, $E = f(V, \sigma V, K, c, r)$ and volatility of equity, $\sigma E = g(V, \sigma V, K, c, r)$. where K denotes the leverage ratio in the capital structure, c is the average coupon paid on the long-term debt, r is the risk-free rate.
- Solve for V and σE from the above 2 equations.

ii. Distance to Default

Default point, d* = short-term debt +1/2 X long-term debt

Distance to default = df = E(Vt) – d* / σV OR (In Vo/d* + (μ - σ^2v/2) T)/ σv √T

Where σv is the current market value of firm, μ is the expected net return on firm value and is the annualized firm value volatility.

Example:

Current market value of assets	Vo = 1,000
Net expected growth of assets per annum	μ = 20%
Expected asset value in one year	VT = 1,200
Annualized asset volatility	σV = 100
Default point	d* = 800
Default Distance	df = 1200 -800 / 100 = 4

Among the population of all the firms with df = 4 at one point in time, say 5,000 firms, 20 defaulted in one year. Then

EDF 1 Year = 20 / 5000 = 0.004 = 40 bp

iii. Key Features of KMV Model

- Dynamics of EDF comes mostly from the dynamics of the equity values.
- Distance to default ratio determines the level of default risk. This key ratio compares the firm's net worth to its volatility. The net worth is based on values from the equity market, so it is both timely and superior estimate of the firm value.
- Ability to adjust to the credit cycle and ability to quickly reflect any deterioration in credit quality.
- Work best in highly efficient liquid market conditions.

iv. Limitations of KMV Model

- It requires some subjective estimation of the input parameters.
- It is difficult to construct theoretical EDF's without the assumption of normality of asset returns.
- Private firms' EDFs can be calculated only by using some comparability analysis based on accounting data.
- It does not distinguish among different types of long-term bonds according to their seniority, collateral, covenants, or convertibility.

V. Management of Credit Risk

Credit risk is managed with both short-term and long-term focus.

1. Credit Forwards (Interest Rate Forwards)

A forward rate agreement (FRA) is a forward contract, an over-the-counter contract between parties that determines the rate of interest, or the currency exchange rate, to be paid or received on an obligation beginning at a future start date. The contract will determine the rates to be used along with the termination date and notional value. On this type of agreement, it is only the differential that is paid on the notional amount of the contract. It is paid on the effective date. The reference rate is fixed one or two days before the effective date, dependent on the market convention for the particular currency. FRAs are over-the counter derivatives. An FRA differs from a swap in that a payment is only made once at maturity.

Many banks and large corporations will use FRAs to hedge future interest rate exposure. The buyer hedges against the risk of rising interest rates, while the seller hedges against the risk of falling interest rates. Other parties that use Forward Rate Agreements are speculators purely looking to make bets on future directional changes in interest rates.

In other words, a forward rate agreement (FRA) is a tailor-made, over-the-counter financial futures contract on short-term deposits. An FRA transaction is a contract between two parties to exchange payments on a deposit, called the Notional amount, to be determined on the basis of a short-term interest rate, referred to as the Reference rate, over a predetermined time period at a future date. FRA transactions are entered as a hedge against interest rate changes. The buyer of the contract locks in the interest rate in an effort to protect against an interest rate increase, while the seller protects against a possible interest rate decline. At maturity, no funds exchange hands; rather, the difference between the contracted interest rate and the market rate is exchanged. The buyer of the contract is paid if the reference rate is above the contracted rate, and the buyer pays to the seller if the reference rate is below the contracted rate. A company that seeks to hedge against a possible increase in interest rates would purchase FRAs, whereas a company that seeks an interest hedge against a possible decline of the rates would sell FRAs.

The formula for the calculation of the payment of FRA is as follows:

$$\text{Payment} = \text{Notional Amount} * \left(\frac{(\text{Reference Rate} - \text{Fixed Rate}) * \alpha}{1 + \text{Reference Rate} * \alpha} \right)$$

- The Fixed Rate is the rate at which the contract is agreed.
- The Reference Rate is typically Euribor or LIBOR.
- α is the day count fraction, i.e. the portion of a year over which the rates are calculated, using the day count convention used in the money markets in the underlying currency. For EUR and USD this is generally the number of days divided by 360, for GBP it is the number of days divided by 365 days.

The Fixed Rate and Reference Rate are rates that should accrue over a period starting on the effective date, and then paid at the end of the period (termination date). However, as the payment is already known at the beginning of the period, it is also paid at the beginning. This is why the discount factor is used in the denominator.

2. Credit Futures (Interest Rate Futures)

Credit futures are similar to credit forwards in terms of calculations however the structure is different in terms of implementation of contract. These differences are summarized below:

Parameters	Futures	Forwards
Default Risk	Borne by Exchange	Borne by Counter Parties

What to Trade	Standardized	Negotiable
Where to Trade	Standardized	Negotiable
When to Trade	Standardized	Negotiable
How Much to Trade	Standardized	Negotiable
What Type to Trade	Standardized	Negotiable
Contract Price	Mark to Market	Negotiable
Security	Margin Required	Negotiable Collateral

Buying an interest rate futures contract allows the buyer of the contract to lock in a future investment rate; not a borrowing rate as many believe. Interest rate futures are based off an underlying security which is a debt obligation and moves in value as interest rates change.

When interest rates move higher, the buyer of the futures contract will pay the seller in an amount equal to that of the benefit received by investing at a higher rate versus that of the rate specified in the futures contract. Conversely, when interest rates move lower, the seller of the futures contract will compensate the buyer for the lower interest rate at the time of expiration.

To accurately determine the gain or loss of an interest rate futures contract, an interest rate futures price index was created. When buying, the index can be calculated by subtracting the futures interest rate from 100, or (100 - Futures Interest Rate). As rates fluctuate, so does this price index. You can see that as rates increase; the index moves lower and vice versa.

Typically, the interest rate futures contract has a base price move (tick) of .01, or 1 basis point however, some contracts have a tick value of .005 or half of 1 basis point. For example, for Eurodollar contracts, a tick is worth $12.50 and a move from 94 to 94.50 would result in a $1250 gain per contract for someone who is long the futures.

Many participants in the interest rate futures market hedge their positions that have an interest rate risk with an offsetting futures contract. As the hedge becomes profitable and traders see less risk in the market, the hedge will be peeled off.

Other participants will use interest rate futures to hedge forward borrowing rates. For example, it is currently March and I need to borrow money in June for 1 month at Libor plus 2. The current LIBOR rate is 2.75%, and let's says the 3-month LIBOR futures are 3%. I will basically be locking in a 5% forward rate by shorting or selling the LIBOR June1 month LIBOR futures contracts.

3. Credit Swaps

A swap is a derivative in which counterparties exchange certain benefits of one party's financial instrument for those of the other party's financial instrument. The benefits in question depend on the type of financial instruments involved. For example, in the case of a swap involving two bonds, the benefits in question can be the periodic interest (or coupon) payments associated with the bonds. Specifically, the two counterparties agree to exchange one stream of cash flows against another stream. These streams are called the legs of the swap. The swap agreement defines the dates when the cash flows are to be paid and the way they are calculated. Usually at the time when the contract is initiated at least one of these series of cash flows is determined by a random or uncertain variable such as an interest rate, foreign exchange rate, equity price or commodity price.

The cash flows are calculated over a notional principal amount, which is usually not exchanged between counterparties. Consequently, swaps can be in cash or collateral.

Swaps can be used to hedge certain risks such as interest rate risk, or to speculate on changes in the expected direction of underlying prices.

Swaps were first introduced to the public in 1981 when IBM and the World Bank entered into a swap agreement. Today, swaps are among the most heavily traded financial contracts in the world. Most swaps are traded over-the-counter (OTC), "tailor-made" for the counterparties. The five generic types of swaps, in order of their quantitative importance, are: interest rate swaps, currency swaps, credit swaps, commodity swaps and equity swaps.

i. Interest Rate Swaps

The most common type of swap is a “plain Vanilla” interest rate swap. It is the exchange of a fixed rate loan to a floating rate loan. The life of the swap can range from 2 years to over 15 years. The reason for this exchange is to take benefit from comparative advantage. Some companies may have comparative advantage in fixed rate markets while other companies have a comparative advantage in floating rate markets. When companies want to borrow, they look for cheap borrowing i.e. from the market where they have comparative advantage. However, this may lead to a company borrowing fixed when it wants floating or borrowing floating when it wants fixed. This is where a swap comes in. A swap has the effect of transforming a fixed rate loan into a floating rate loan or vice versa. For example, party B makes periodic interest payments to party A based on a variable interest rate of LIBOR +70 basis points. Party A in return makes periodic interest payments based on a fixed rate of 8.65%. The payments are calculated over the notional amount. The first rate is called variable, because it is reset at the beginning of each interest calculation period to the then current reference rate, such as LIBOR. In reality, the actual rate received by A and B is slightly lower due to a bank taking a spread.

The present value of a plain vanilla (i.e. fixed rate for floating rate) swap can easily be computed using standard methods of determining the present value (PV) of the fixed leg and the floating leg.

The value of the fixed leg is given by the present value of the fixed coupon payments known at the start of the swap, i.e.

$$PV_{\text{fixed}} = C \times \sum_{i=1}^{M} (P \times \frac{t_i}{T_i} \times df_i)$$

Where C is the swap rate, M is the number of fixed payments, P is the notional amount, ti is the number of days in period i, Ti is the basis according to the day count convention and dfi is the discount factor.

Similarly, the value of the floating leg is given by the present value of the floating coupon payments determined at the agreed dates of each payment. However, at the start of the swap, only the actual payment rates of the fixed leg are known in the future, whereas the forward rates (derived from the yield curve) are used to approximate the floating rates. Each variable rate payment is calculated based on the forward rate for each respective payment date. Using these interest rates leads to a series of cash flows. Each cash flow is discounted by the zero-coupon rate for the date of the payment; this is also sourced from the yield curve data available from the market. Zero-coupon rates are used because these rates are for bonds which pay only one cash flow. The interest rate swap is therefore treated like a series of zero-coupon bonds. Thus, the value of the floating leg is given by the following:

$$PV_{\text{float}} = \sum_{j=1}^{N} (P \times f_j \times \frac{t_j}{T_j} \times df_j)$$

Where N is the number of floating payments, fj is the forward rate, P is the notional amount, tj is the number of days in period j, Tj is the basis according to the day count convention and dfj is the discount factor. The discount factor always starts with 1. The discount factor is found as follows:

[Discount factor in the previous period] / [1 + (Forward rate of the floating underlying asset in the previous period × Number of days in period/360)].

The fixed rate offered in the swap is the rate which values the fixed rates payments at the same PV as the variable rate payments using today's forward rates, i.e.:

$$C = \frac{PV_{\text{float}}}{\sum_{i=1}^{M}(P \times \frac{t_i}{T_i} \times df_i)}$$

Therefore, at the time the contract is entered into, there is no advantage to either party, i.e.

$$PV_{\text{fixed}} = PV_{\text{float}}$$

Thus, the swap requires no upfront payment from either party.

During the life of the swap, the same valuation technique is used, but since, over time, the forward rates change, the PV of the variable-rate part of the swap will deviate from the unchangeable fixed-rate side of the swap. Therefore, the swap will be an asset to one party and a liability to the other.

ii. Credit Default Swaps

A credit default swap (CDS) is a swap contract in which the buyer of the CDS makes a series of payments to the seller and, in exchange, receives a payoff if an instrument - typically a bond or loan - goes into default (fails to pay). Less commonly, the credit event that triggers the payoff can be a company undergoing restructuring, bankruptcy or even just having its credit rating downgraded. CDS contracts are compared with insurance because the buyer pays a premium and in return receives a sum of money if one of the events specified in the contract occur. Unlike an actual insurance contract, the buyer is allowed to profit from the contract and may also cover an asset to which the buyer has no direct exposure.

In brief, a CDS is used to transfer the credit risk of a reference entity (corporate or sovereign) from one party to another. In a standard CDS contract one party purchases credit protection from another party, to cover the loss of the face value of an asset following a credit event. A *Credit Event* is a legally defined event that typically includes bankruptcy, failure-to-pay and restructuring. This protection lasts until some specified maturity date. To pay for this protection, the protection buyer makes a regular stream of payments, known as the *Premium Leg*, to the protection seller. This size of these premium payments is calculated from a quoted default swap *Spread* which is paid on the face value of the protection. *Spread* is the cost per annum for protection against a default by the company. These payments are made until a credit event occurs or until maturity, whichever occurs first.

If a credit event does occur before the maturity date of the contract, there is a payment by the protection seller, known as the *Protection Leg*. This payment equals the difference between par and the price of the cheapest to deliver (CTD) asset of the reference entity on the face value of the protection and compensates the protection buyer for the loss. It can be made in cash or physically settled format.

Suppose a protection buyer purchases 5-year protection on a company at a default swap spread of 300bp. The face value of the protection is $10 million. The protection buyer therefore makes quarterly payments approximately equal to $10 million × 0.03 × 0.25 = $75,000. Assume that after a short period the reference entity suffers a credit event and that the CTD asset of the reference entity has a recovery price of $45 per $100 of face value. The payments are as follows:

- The protection seller compensates the protection buyer for the loss on the face value of the asset received by the protection buyer. This is equal to $10 million × (100% – 45%) = $5.5 million.

- The protection buyer pays the accrued premium from the previous premium payment date to time of the credit event. For example, if the credit event occurs after a month, then the protection buyer pays approximately \$10 million × 0.03 × 1/12 = \$18,750 of premium accrued. Note that this is the standard for corporate reference entity linked default swaps. For sovereign-linked default swaps there may be no payment of premium accrued.

Unlike bonds, the gain or loss from a CDS position cannot be computed simply by taking the difference between current market quoted price plus the coupons received and the purchase price. To value a CDS we need to use a term structure of default swap spreads, a recovery rate assumption and a model.

To see this, consider an investor who initially buys 5-year protection on a company at a default swap spread of 60bp and then wishes to value the position after one year. On that date the 4-year credit default swap spread quoted in the market is 170bp. What is the current value of the position? This is given by:

MTM = Current Market Value of Remaining 4-year *Protection Leg* – Expected Present Value of 4-year *Premium Leg* at 60bp

Where,
MTM = Mark to Market Value
Protection Leg = Money that you will receive in case of default.
Premium Leg = Money that you will be paying for swap.

The key to understanding Hull's valuation of a credit default swap (CDS) is to realize that we are solving for the unknown spread (given by s) that calibrates an equality: the present value (PV) of the expected payments made by the CDS buyer should equal the PV of the expected payoff received by the CDS buyer (i.e., the contingency payoff made by the CDS seller in the event of a default). The payments are like insurance premiums; the payoff is like an insurance claim. The CDS buyer should expect a fair deal, on a probability-adjusted, and present-value, basis.

A credit default swap is, essentially, an insurance contract between a protection buyer and a protection seller covering a corporation, or sovereigns (the "referenced entity"), specific bond or loan. A protection buyer pays an upfront amount and yearly premiums to the protection seller to cover any loss on the face amount of the referenced bond or loan. Typically, the insurance is for five years.

Credit default swaps are bilateral contracts, meaning they are private contracts between two parties. CDSs are subject only to the collateral and margin agreed to by contract. They are traded over-the-counter, usually by telephone. They are subject to re-sale to another party willing to enter into another contract. Most frighteningly, credit default swaps are subject to "counterparty risk."

If the party providing the insurance protection – once it has collected its upfront payment and premiums – doesn't have the money to pay the insured buyer in the case of a default event affecting the referenced bond or loan (think hedge funds), or if the "insurer" goes bankrupt (Bear Stearns was almost there, and American International Group Inc. (AIG) was almost there) the buyer is not covered – period. The premium payments are gone, as is the insurance against default.

Credit default swaps are not standardized instruments. In fact, they technically aren't true securities in the classic sense of the word in that they're not transparent, aren't traded on any exchange, aren't subject to present securities laws, and aren't regulated. They are, however, at risk – all \$62 trillion (the best guess by the ISDA) of them.

Fundamentally, this kind of derivative serves a real purpose – as a hedging device. The actual holders, or creditors, of outstanding corporate or sovereign loans and bonds might seek insurance to guarantee that the debts they are owed are repaid. That's the economic purpose of insurance.

iii. Total Return Swaps

A Total Return Swap (TRS) is a bilateral financial transaction where the counterparties swap the total return of a single asset or basket of assets in exchange for periodic cash flows, typically a floating rate such as LIBOR +/- a basis point spread and a guarantee against any capital losses. A TRS is similar to a plain vanilla swap except the deal is structured such that the total return (cash flows plus capital appreciation/depreciation) is exchanged, rather than just the cash flows.

A key feature of a TRS is that the parties do not transfer actual ownership of the assets, as occurs in a repo transaction. This allows greater flexibility and reduced up-front capital to execute a valuable trade. This also means Total Return Swaps can be more highly leveraged, making them a favorite of hedge funds.

A TRS is made up of two legs, the Return Leg (or Total Return Leg) and the Funding Leg. The reference asset or basket of assets exists on the Return Leg. The cash flow payment stream exists on the Funding Leg.

The *Return Leg* is generally made up of two components: cash flows and capital appreciation of the reference asset(s). The *Funding Leg* also has two components: floating coupons based on LIBOR +/- a spread and payments to offset any capital depreciation of the reference asset(s).

Additional legs may be structured to account for reinvestment of returns, interest payments on collateral / haircuts, multi-currency flows, or differing payment schedules. Fees, spreads, principal payments, etc. may be added in a customized structure.

The Return Leg counterparty is called the Total Return Payer, Swap Seller, Buyer of protection, or Beneficiary. Here, we will use the term Total Return Payer or TRP. The TRP (typically a bank, fund, or dealer) has a long position in the reference asset or basket of assets, holding them on its balance sheet. The TRP "buys protection" on these asset returns by agreeing to pay all of the future returns of the reference asset(s) in exchange for a floating stream of payments, usually LIBOR +/- a spread, plus a guaranteed offset of any capital losses incurred by the reference asset(s). The TRP gives up one set of expected future returns (capital appreciation, coupons, fees, dividends, etc.) in exchange for another set of future returns (LIBOR coupons +/- a spread) and capital loss insurance. This allows the TRP to lock in the value of its asset(s) and receive additional income.

The Funding Leg counterparty is called the Total Return Receiver, Swap Buyer, Seller of protection, or Guarantor. Here, we will use the term Total Return Receiver or TRR. The TRR seeks exposure to the returns of the reference asset or basket of assets, but does not want to purchase and hold them on its balance sheet. This party "sells protection" on the TRP's asset(s) by taking a synthetic long position in the asset(s) and making regular floating cash flow payments and capital loss guarantee payments to the TRP. The TRR seeks leveraged returns, and will pay for access to those returns, while taking on the risk of capital losses.

Total Return Payers are usually large institutions with big balance sheets such as commercial banks, investment banks, mutual funds, securities dealers, and insurance companies. Total Return Payers have lower cost of funding than Total Return Buyers, but their returns are often limited by regulatory capital requirements or conservative strategies. By "leasing" a portion of its strong balance sheet with a TRS, a TRP can achieve higher returns while ensuring against capital losses.

The exchange of cash flows and risks are explained below:

Total Return Payer (TRP):

- Owns reference asset(s)
- Has lower cost financing
- Pays total return of asset(s)
- Receives LIBOR +/- spread

- Receives payments to offset any capital losses
- Takes on interest rate risk
- Transfers away asset return risk

Total Return Receiver (TRR):

- Does not own reference asset(s) - has a weaker balance sheet or uses balance sheet leverage
- Has higher cost financing
- Receives total return of asset(s)
- Pays LIBOR +/- spread
- Pays for any capital losses
- Takes on asset return risk
- Takes on interest rate risk

i. Valuation of Total Return Swaps

The value of a swap is the net present value (NPV) of all estimated future cash flows. A swap is worth zero when it is first initiated, however after this time its value may become positive or negative. There are two ways to value swaps: in terms of bond prices, or as a portfolio of forward contracts.

While principal payments are not exchanged in an interest rate swap, assuming that these are received and paid at the end of the swap does not change its value. Thus, from the point of view of the floating-rate payer, a swap is equivalent to a long position in a fixed-rate bond (i.e. receiving fixed interest payments), and a short position in a floating rate note (i.e. making floating interest payments):

$$V_{\text{swap}} = B_{\text{fixed}} - B_{\text{floating}}$$

From the point of view of the fixed-rate payer, the swap can be viewed as having the opposite positions. That is,

$$V_{\text{swap}} = B_{\text{floating}} - B_{\text{fixed}}$$

Payments Received by Total Return Receiver:

- If reference asset is a bond, the bond coupon
- The price appreciation, if any, of the reference asset since the last fixing date
- If the reference asset is a bond that defaulted since the last fixing date, the recovery value of the bond
- Interest on any collateral / haircut being held by the Total Return Payer

Payments Received by the Total Return Payer:

- The periodic floating payment (usually LIBOR +/- a spread)
- The price depreciation, if any, of the reference asset since the last fixing date
- If the reference asset is a bond that defaulted since the last fixing date, the par value of the bond

SOLVENCY RISK

(Theory, Calculations and Practical Concepts)

I. Definition of Solvency Risk

Solvency risks represent the risk that business losses will be greater than what can be absorbed by the capital side of balance sheet, thereby reducing capital from required level and making business insolvent.

Solvency risk can be controlled by having a sound capital on balance sheet and not exposing it to risks which are beyond prescribed limits in order to avoid losses.

II. Measurement of Solvency Risk (Solvency Risk Metrics)

The capital requirement is a bank regulation, which sets a framework on how banks and depository institutions must handle their capital. The categorization of assets and capital is highly standardized so that it can be risk weighted.

Internationally, the Basel Committee on Banking Supervision housed at the Bank for International Settlements influence each country's banking capital requirements. In 1988, the Committee decided to introduce a capital measurement system commonly referred to as the Basel Accord. This framework has been replaced by a significantly more complex capital adequacy framework commonly known as Basel II. After 2012 it will be replaced by Basel III.

Basel Accord divides capital in 3 tiers known as *Core Capital or Tier I Capital, Supplementary Capital or Tier II Capital* and *Tertiary Capital or Tier III Capital*.

1. Core Capital – Tier I (Permanent Capital)

Core Capital or Tier I Capital is the most important form of capital. This is the part of capital which is permanent in nature as it is not required to be redeemed at all. This form of capital consists of Shareholders' Equity at Book Value.

In simple terms Core Capital includes those components of capital that cannot be redeemed at the option of holder. These components are easy to calculate and liquidate.

Core Capital = Common Equity + Disclosed Revenue Reserves + Disclosed Capital Reserves + Non-Cumulative Perpetual Preferred Equity

2. Supplementary Capital – Tier II (Medium Term Capital)

There are several classifications of Tier II Capital, which is composed of supplementary capital and are called temporary capital unlike Tier I which is permanent capital. In the Basel I accord, these are categorized as undisclosed reserves, revaluation reserves, general provisions, hybrid instruments and subordinated term debt.

In simple terms Supplementary Capital includes those components of capital that can either be redeemed in long term or change in value. These components are difficult to calculate and liquidate.

Supplementary Capital = Undisclosed Revenue Reserves + Revaluation Reserves + General Provisions + Long Term Sub-Ordinated Debts + Long Term Redeemable Preferred Equity

i. Undisclosed Revenue Reserves

Undisclosed reserves are not common, but are accepted by some regulators where a Bank has made a profit but this has not appeared in normal retained profits or in general reserves. Most of the regulators do not allow this type of reserve because it does not reflect a true and fair picture of the results. However, undisclosed reserves must have passed though PNL in order to qualify for Tier II Capital.

ii. Revaluation Reserves
A revaluation reserve is a reserve created when a company has an asset revalued and an increase in value is brought to account. A simple example may be where a bank owns the land and building of its headquarters and bought them for $100 a century ago. A current revaluation is very likely to show a large increase in value. The increase would be added to a revaluation reserve.

iii. General Provisions
A general provision is created when a company is aware that a loss may have occurred but is not sure of the exact nature of that loss. Under pre-IFRS accounting standards, general provisions were commonly created to provide for losses that were expected in the future. As these did not represent incurred losses, regulators tended to allow them to be counted as capital.

iv. Long Term Sub-Ordinated Debts
Subordinated debt is classed as Lower Tier 2 debt, usually has a maturity of a minimum of 10 years and ranks senior to Tier 1 debt, but subordinate to senior debt. To ensure that the amount of capital outstanding doesn't fall sharply once a Lower Tier 2 issue matures and, for example, not be replaced, the regulator demands that the amount that is qualifiable as Tier 2 capital amortizes on a straight-line basis from maturity minus 5 years. The remainder qualifies as senior issuance. For this reason, many Lower Tier 2 instruments were issued as 10yr non-call 5-year issues i.e. final maturity after 10 years but callable after 5 years. If not called, issue has a large step - similar to Tier 1 - thereby making the call more likely.

3. Tertiary Capital – Tier III (Short Term Capital)
This is the most inferior type of capital as it can disappear in short term. Tertiary Capital includes those components of capital that can be redeemed in short term and banks use it to manage market risk. This capital is composed of Short Term Unsecured Sub-Ordinated Debts with a minimum maturity of 2 years.

4. Tier I Capital Ratio
Tier I Capital Ratio is a regulatory ratio which is calculated as follows:

Tier I Capital Ratio = Tier I Capital / Risk Weighted Assets

Where *Risk Weighted Assets (RWA)* are calculated by assigning following weights to the assets on balance sheets:

Cash =	0% Risk
Sovereign Receivables =	0% Risk
Secured Mortgages =	50% Risk
All Other Assets =	100% Risk
All Other Receivables =	100% Risk

Tier I Capital Ratio should be equal to or greater than 6% as per current Basel Guidelines.

5. Capital Adequacy Ratio (CAR)
Capital Adequacy Ratio which is also known as Total Capital Ratio is also a regulatory ratio. It is similar to Tier I Capital Ratio and the only difference is that it includes both Tier I and Tier II types of capital. Capital Adequacy Ratio is calculated as follows:

CAR = Tier I Capital + Tier II Capital / Risk Weighted Assets

Risk Weighted Assets in CAR are same as Tier I Capital Ratio. CAR should be equal to or greater than 10% as per current Basel Guidelines.

6. Leverage Ratio
Leverage Ratio basically shows the relation between Tier I Capital and total assets of a bank or in simple terms it shows what percentage of assets is being financed through permanent equity. Leverage Ratio is calculated as follows:

Leverage Ratio = Tier I Capital / Total Average Assets

Leverage Ratio should be equal to or greater than 5% as per current Basel Guidelines.

7. Equity Ratio
Equity Ratio is similar to Leverage Ratio. The only difference is that it is stricter as it only includes Common Shareholders' Equity in showing the relationship between assets and capital. Equity ratio is calculated as follows:

Equity Ratio = Common Shareholders' Equity / Balance Sheet Assets

III. Management of Solvency Risk

1. Regulatory Capital Management – (Basel Guidelines)
Regulatory Capital is managed by following Regulatory Capital Requirements which are prescribed by Basel Guidelines. Regulatory Capital Requirements basically sets a minimum limit to the capital that needs to be maintained at all times in order to keep the balance sheet solvent. The minimum limit of capital is calculated on the basis of risk adjusted assets and is represented by ratios. Each bank has to calculate these ratios and declare them in the balance sheets.

Given below is the summary of Regulatory Capital Requirements:

- Tier I Capital Ratio should be equal to or greater than 6%
- Tier I & II Capital Ratio also called Capital Adequacy Ratio should be equal to or greater than 10%
- Tier I Capital should be equal to or greater than 5% of Total Average Assets.

2. Economic Capital Management
Economic Capital is a concept in risk management that calculates the amount of capital required to remain solvent when assets and liabilities are converted into fair market values instead of book value. Therefore, Economic Capital calculates the capital requirements as per current market conditions. The values of assets and liabilities are calculated by using Value at Risk (VaR) methodology with a confidence level of 99.5 to 99.9%.

In simple terms, Economic Capital is the amount of risk capital, assessed on a realistic basis, which a firm requires to cover the risks that it is running or collecting as a going concern, such as market risk, credit risk, and operational risk. It is the amount of money which is needed to secure survival in a worst-case scenario. Firms and financial services regulators should then aim to hold risk capital of an amount equal at least to economic capital.

The concept of economic capital differs from regulatory capital in the sense that regulatory capital is the mandatory capital the regulators require to be maintained while economic capital is the best estimate of required capital that financial institutions use internally to manage their own risk and to allocate the cost of maintaining regulatory capital among different units within the organization.

Advantage of Economic Capital calculation is that it helps a bank or financial institution to manage its capital on short term basis and long-term disasters are avoided by creating reserves for capital on a regular basis.

Calculation of Economic Capital requires very clear policy regarding 5 important factors that would have an impact on the value of final calculations. These factors are:

- What Risks? This means what risks will a company use to adjust its assets and liabilities i.e. market risks, credit risks, operational risks etc.
- What Confidence Level? This means what level of confidence should be used to calculate the risk adjusted values of assets and liabilities i.e. 95%, 99%, 99.5% etc.
- What Frequency? This means how often a firm should calculate the economic capital i.e. yearly basis, semi yearly basis, quarterly basis etc.
- What Capital Definition? This means which definition of capital a firm is using in calculations i.e. GAAP definition, IFRS definition, regulatory capital etc.
- What Methodology? This means which methodology a firm will use to calculate the economic capital i.e. Scenario modeling, Static Factor modeling, Covariance modeling etc.?

Economic Capital is calculated by using 3 types of models i.e. *Scenario Models, Static Factor Models* and *Covariance Models.*

i. Scenario Models

In scenario-based modeling capital is calculated by measuring the impact of specific scenarios to the distribution of loss. These scenarios simultaneously cover multiple risk drivers. The approach is different from stress test, under which only one shock is given to specific risk drivers. Correlation between risk drivers must be taken into account when stochastic scenarios are generated.

ii. Static Factor Models

A static factor model is based on linear combination of static risk factors multiplied by the company-specific amount which are typically accounting items such as amount of a specific asset class or premium income. A stochastic factor model is processed in following steps:

- Identify relevant risk drivers.
- Calculate sensitivities by Greeks.
- Integrate impact of all risk drivers.
- Calculate total loss resulting from integrated risk drivers.
- Distribute total loss to PNL.
- Rebuild balance sheet taking total loss into account.
- Calculate the amount of capital required.

iii. Covariance Models

A covariance model is a special case of a stochastic factor model with multi normal distributions, first order sensitivities and VaR as risk measure. Covariance model is not very popular in modern risk management practices. The accuracy of covariance model however can be improved by including sub-risk classification including the risk components volatility, uncertainty and calamity.

3. Risk Adjusted Returns on Capital – RAROC

Risk adjusted return on capital (RAROC) is a risk-based profitability measurement framework for analyzing risk-adjusted financial performance and providing a consistent view of profitability across businesses. The concept was developed by Bankers Trust and principal designer Dan Borge in the late 1970s.

RAROC is a ratio that compares the amount of Economic Capital needed to secure a certain investment with the likely returns on investment adjusted for risks. Formula for RAROC is as follows:

RAROC = (Revenue + Income Derived from Capital - Operating Expenses – Expected Losses) / Economic Capital

Where,

Income Derived from Capital = Capital Charge X Risk Free Returns

And where,

Capital Charge = Capital X Weighted Average Cost of Capital (WACC)

In simple terms, RORAC is equal to Expected Returns divided by either Economic Capital or VaR. Broadly speaking, in business enterprises; risk is traded off against benefit. RAROC is defined as the ratio of risk adjusted return to economic capital. The economic capital is the amount of money which is needed to secure the survival in a worst-case scenario; it is a buffer against expected shocks in market values. Economic capital is a function of market risk, credit risk, and operational risk, and is often calculated by VaR. This use of capital based on risk improves the capital allocation across different functional areas of banks, insurance companies, or any business in which capital is placed at risk for an expected return above the risk-free rate.

4. Returns on Risk Adjusted Capital – RORAC

This calculation is similar to risk-adjusted return on capital (RAROC); however, with RORAC, the capital is adjusted for risk, not the rate of return. RORAC is used when the risk varies depending on the capital asset being analyzed.

A rate of return used in financial analysis, whereby riskier projects and investments are evaluated based on the capital at risk. RORAC makes it easier to compare and contrast projects with different risk profiles. Formula for RORAC is as follows:

RORAC = Net Income / Allocated Risk Capital

Where,

Allocated Risk Capital (ARC) = Firm's capital adjusted for maximum potential losses based on volatility of earnings.
For the calculation of Allocated Risk Capital (ARC), capital is adjusted for 5 main risk metrics i.e. *Alpha, Beta, R-Squared, Standard Deviation* and *Sharpe Ratio*.

R-Squared is a statistical measure that represents the percentage of a fund or security's movements that can be explained by movements in a benchmark index. R-squared values range from 0 to 100. R-squared value of 100 means that all movements of a security are completely explained by movements in the index. A high R-squared (between 85 and 100) indicates the fund's performance patterns have been in line with the index. A fund with a low R-squared (70 or less) doesn't act much like the index.

A higher R-squared value will indicate a more useful beta figure. For example, if a fund has an R-squared value of close to 100 but has a beta below 1, it is most likely offering higher risk-adjusted returns. A low R-squared means you should ignore the beta.

5. Risk Adjusted Returns on Risk Adjusted Capital – RARORAC

RARORAC simply combines RAROC and RORAC. It shows the relation of risk adjusted returns to risk adjusted capital. Formula for calculation of RARORAC is as follows:

RARORAC = (Revenue + Income Derived from Capital - Operating Expenses – Expected Losses) / Allocated Risk Capital

Where,

Income Derived from Capital = Capital Charge X Risk Free Returns

Capital Charge = Capital X Weighted Average Cost of Capital (WACC)

Allocated Risk Capital = Capital adjusted for Alpha, Beta, R-Squared, Standard Deviation and Sharpe Ratio.

RISK AUDIT

(Theory, Calculations and Practical Concepts)

I. Concept of Risk Audit

Audits are an essential component to an organization's security strategy. They enable staff to meet regulatory requirements, validate that existing controls protect business functions, and determine when new controls are required. Unlike an audit in which the auditor uses a checklist and pen to determine compliance, a risk-based audit requires having an understanding of the organization's business functions and objectives -- to really dig deep within systems and networks.

According to the Information Systems Audit and Control Association, or ISACA, "In a risk-based audit approach, auditors are not just relying on risk; they also are relying on internal and operational controls as well as knowledge of the company or the business."

Thus, a risk-based audit provides a more thorough assessment of business risk, and enables managers to make informed decisions based on their risk appetites. Aligning enterprise IT decisions and practices with the level of acceptable risk in an organization is the driver for beginning a risk-based audit, and it is the risk assessment process that helps determine that risk threshold.

II. Preparation of Risk Audit

Any risk audit has three objectives and it requires a thorough preparation before embarking upon a mega scale of auditing business risks. These objectives are as follows:

- Reconciliation of Risk Register with Accounts.
- Consolidation of Risk Register with Risk Policies & Guidelines.
- Testing of Risk Practices against Risk Policies & Controls.

Meeting these objectives requires a seven-step process which is described as under:

i. Risk Assessment

Risk appetite or acceptable risk is the amount of risk exposure that a business is willing to accept. That is, the organization must set a threshold for identifying when and where to implement controls to mitigate risk.

This process is essential to determining what controls are "nice to have" vs. those necessary to protect business functions. Several risk management methodologies, such as those by the International Organization for Standardization (ISO) and the National Institute of Standards and Technology (NIST), provide managers with good estimates for assessing acceptable risk. In some manner, those methodologies commonly include identifying assets, threats, vulnerabilities and controls.

ii. Identifying Assets

Organizations cannot protect what they are not aware of, so they must identify all assets, with a sharp focus on those most critical. Once a full list of assets is obtained, the organization must categorize them using some taxonomy, or categorization criteria. In a basic sense, assets can be categorized and assessed by:

- Type: information, hardware, software, services, etc.
- Value: value to business and competition
- Complexity: abnormal overhead, compatibility, or operational requirements
- Age: period of operation, breakdown history and projected lifespan

iii. Determining Criticality and Confidentiality Levels
Once assets are categorized, the next step is to assign criticality and confidentiality levels. Criticality and confidentiality levels serve to dictate the specific controls for groups of assets, based on confidentiality, integrity and availability requirements. The below criteria offer an easy approach to assigning criticality and confidentiality levels to assets:

Criticality levels based on integrity and availability requirements:
- Criticality Level 1 (High level of protection): vital to the sustainment of business operations (e.g., a stock-trading server for a stock-trading company).
- Criticality Level 2 (Medium level of protection): important to supporting business operations (e.g., a mail server for a stock-trading company).
- Criticality Level 3 (Basic level of protection): necessary for day-to-day business operations (e.g., a print server for a stock-trading company).

Classification levels based on confidentiality requirements:
- Confidential: unauthorized disclosure could have grave consequences for the company (e.g., trade secrets, source code, etc.).
- Private: unauthorized disclosure could affect image of company (e.g., personnel data, financial information, etc.).
- Public: no negative impact towards company (e.g., new services, leadership bios, etc.).

iv. Threat and Vulnerability Identification
After identifying, classifying and assigning criticality levels to assets; the next step is to identify their threats and vulnerabilities. Threats occur because of vulnerabilities. Vulnerabilities are weaknesses in people, processes and technology, and are exploited by threats. For instance, malicious software (or malware) is a threat that can exploit the vulnerability of having non-patched systems. Another potential threat is a black out, which can exploit the lack of having building generators. Threats are categorized by business, technical, physical and administrative. It is important for organizations to not only be aware of their threats and vulnerabilities, but also understand them to determine the level of risk they pose and required countermeasures.

v. Risk Calculations
Calculating risk is essential to determining the best use of resources. A simple formula for calculating risk is, risk = asset value x threat x vulnerability. Remember from the description above that the asset value is more than its initial cost. The value of an asset increases as resources are applied, and as competitors value it. Resources are applied towards assets in development, testing, operations and maintenance. In addition, the information within an asset is of value. For example, let's look at a Web server that accepts customer information. If the database that contains customer information is compromised, its loss may cause legal penalties and reputation damage. In addition, loss of trade secrets can cause a decrease in market share and in competitive advantage. Therefore, asset value must take into account all factors that affect its value.

Calculating a threat value requires looking at its estimated projected loss (PL) and annual rate of occurrence (ARO). PL is the percentage exposed by the asset if the threat occurs. That is, if malware compromises the database that holds customer information and 60% data loss is anticipated, then PL is 60%. We then look at the threat's ARO by determining how often a threat is projected to occur within a single year. In this case, the projection may be an annual rate of occurrence of once every two years, or .50. This would make our threat calculation .3 (PL x ARO).

The last calculation before determining risk is deficiency level (DL). DL is the amount of protection deficient given controls already in place. That is, if existing antimalware technology in place to protect the company's database is 80% effective, then there is a 20% deficiency level. Using this figure, along with asset value and threat calculations, we can calculate risk. In this example, let's use $500,000 as the value of the database. In such as case, risk = $500,000 x .3 x .20 = $30,000. Under this scenario, we can justify an investment of up to $30,000 to protect the critical database.

The risk assessment process enables audit teams to prioritize engagements based on risk, while remaining focused on critical assets that significantly affect business operations. This risk assessment process is coupled with ranking risks in the audit universe. Remember, these exercises require some estimation, since each attack or threat vector is different.

vi. The Audit Scope

The audit universe includes all potential audit entities and processes that may be assessed by the audit team. Essentially, the audit universe includes the people, processes and technology that drive the organization's business objectives. Examples of potential areas within the audit universe include infrastructure, applications, processes, architectures, regulatory compliance, frameworks, policies and boundary protection. Along with determining risk in monetary terms, another way is by ranking risk using a risk table.

Risk ranking is the process of using judgment to score audit entities. The risk ranking table is calculated using a concern rating scale and the value assigned to each risk area. For instance, the table below regards Web applications as a high-risk area. The table lists Web application complexity as a high concern, which has a concern rating of three. The value assigned to complexity is 1.75; therefore, 1.75 x 3.0 = 5.25, the risk value for Web applications complexity.

The table above provides a high-level example of ranking risk. Given the ranking criteria, the top 25% of audit entities is considered high risk and must be audited in that year. According to this table, all Web applications and Web servers must be audited this year. A more comprehensive risk ranking table could rank specific Web applications, or even each Payment Card Industry Data Security Standard (PCI DSS) requirement as its own auditable entity. The level of detail in listing entities is dependent upon the size of the audit universe and the resources available to perform an in-depth risk ranking assessment. The annual risk assessment and ranking process determines the audit plan.

vii. The Audit Plan

The audit plan outlines the annual audit schedule, scope, objectives and resources required to start audit engagements. The audit plan is created using risk assessment results and risk ranking. The risk assessment truly drives this process as it helps the audit team identify deficiency levels, unaddressed weaknesses, and areas of concern. In addition to the risk ranking criteria shown in the table above, other potential criteria are recent technology refresh, recent mergers, recent acquisitions, new regulations, etc. The audit plan defines roles and responsibilities, the audit team's methodology, logistics and performance measures. Essentially, the audit plan serves as the road map -- with management's approval -- for the audit team to start conducting audits.

III. Risk Audit Process

After the annual process of identifying and ranking risk, and developing the audit plan, the audit team can "roll their sleeves back" and begin auditing. The auditing process involves a phased, five-step risk-based process that includes preparation, assessment, and mitigation, reporting and follow-up. Each phase is explained below.

i. Preparation Phase

The preparation phase involves individual engagement planning before each audit in the audit plan. During this phase, the audit team reviews previous working papers, risk assessment findings, and defines the individual engagement's scope and objectives. The team will listen to the concerns of management and their operators and then compare that information with their assessment results. The audit team's focus is to understand the business objectives and functions of the company to make the most informed assessment.

ii. Assessment Phase

The assessment phase involves analyzing systems and process, identifying vulnerabilities and documenting concerns. During this phase, the auditor may use a checklist, but will rely heavily upon experience and judgment to interpret results and identify less-noticeable anomalies. During this phase, it's important to collaborate with operators to validate the significance of risk. Certain "textbook" findings may seem significant at first, but may be in place for good reason (such as unique operational requirements for certain applications). Therefore, it is important to validate certain results before causing too much stir by listing it as significant on the final report.

Depending on the system, network, or process being audited, some baseline controls exist that they can be assessed against. For instance, the SANS Institute outlines a prioritized list of baseline security controls and measures. These controls were developed by SANS, in collaboration with federal agencies, civilian penetration testers and forensic experts. Some of these controls include inventorying authorized and unauthorized devices, boundary defense, application security, malware defense, data loss prevention, account control, wireless control and data recovery capabilities. In addition to auditing against baseline controls, it is important to ensure controls are in place that enables business functions.

iii. Mitigation Phase

The mitigation phase involves developing the proper controls to mitigate risk. This process involves socializing requirements with the company and developing mitigation plans. While some controls may take weeks or months to implement, others can be rectified on the spot. This phase involves documenting potential controls and the actions taken by operators to mitigate risks on the spot.

iv. Reporting Phase

In the reporting phase, the audit team provides a full report to management outlining its findings. The group will share mitigation plans for ongoing controls, and outline the most significant findings. This phase involves developing an executive summary with key information for managers to make security decisions. The executive summary is a high-level overview that explains "in a nutshell" the security posture of the organization and the next steps required to strengthen their controls.

v. Follow-up Phase

In the follow-up phase, the audit team corresponds and works with the company to ensure controls are implemented. In a resource-constrained environment, the company may lack the skill sets to implement certain control mechanisms. Therefore, the auditors may provide insight into implementing various controls, and will continue to follow up to ensure their implementation. It is important for the audit team to have a process for tracking overdue or upcoming mitigation implementations. The team should create a tracking system that contains an easy-to-follow dashboard that provides the status of implementations and their due dates.

IV. Attribution Analysis

Attribution analysis is a specific type of risk audit. Performance Attribution or Investment Performance Attribution is a set of techniques that performance analysts use to explain why a portfolio's performance differed from the benchmark. This difference between the portfolio returns and the benchmark return is known as the active return. The active return is the component of a portfolio's performance that arises from the fact that the portfolio is actively managed.

Different kinds of performance attribution provide different ways of explaining the active return.

Attribution analysis attempts to distinguish which of the two factors of portfolio performance, superior stock selection or superior market timing, is the source of the portfolio's overall performance. Specifically, this method compares the total return of the manager's actual investment holdings with the return for a predetermined benchmark portfolio and decomposes the difference into a selection effect and an allocation effect.
The attribution analysis dissects the value added into three components:

- *Asset Allocation* is the value added by under-weighting cash and over-weighting equities.
- Stock selection is the value added by decisions within each sector of the portfolio.

- Interaction captures the value added that is not attributable solely to the asset allocation and stock selection decisions.

The three attribution terms (asset allocation, stock selection, and interaction) sum exactly to the active return without the need for any "fudge factors".

i. Approaches of Attribution Analysis

There are two types of attribution analysis i.e. arithmetic approach and geometric approach. A brief description of these approaches is as under:

i. Arithmetic Approach

The most common approach to performance attribution can be described as "arithmetic attribution". It is arithmetic in the sense that it describes the difference between the portfolio return and the benchmark return. For example, if the portfolio return was 21%, and the benchmark return was 10%, arithmetic attribution would explain 11% of value added.

ii. Geometric Approach

In Europe and the UK, another approach known as geometric attribution has been common. If the portfolio return was 21% while the benchmark return was 10%, geometric attribution would explain an active return of 10%. The reasoning behind this is that 10% of active return, when compounded with 10% of benchmark performance, produces a total portfolio return of 21%.

V. PNL Attribution

PNL Explained also called P&L Explain, P&L Attribution or Profit and Loss Explained is a type of report commonly used by traders, especially derivatives (swaps and options) traders, that attributes or explains the daily fluctuation in the value of a portfolio of trades to the root causes of the changes.

P&L is the day-over-day change in the value of a portfolio of trades typically calculated using the following formula:

PNL = Value today - Value from Prior Day.

i. Structure of PNL Attribution Report

A PNL Explained Report will usually contain one row per trade or group of trades and will have at a minimum these columns:

- Column 1: PNL --- This is the PNL as calculated outside of the PNL Explained report.
- Column 2: PNL Explained --- This is the sum of the explanatory columns.
- Column 3: PNL Unexplained --- This is calculated as PNL - PNL Explained (i.e., Column 1 - Column 2).
- Column 4: Impact of Time --- This is the PNL due to the change in time.
- Column 5: Impact of Prices --- This is the PNL due to changes in commodity or equity/stock prices.
- Column 6: Impact of Interest Rates --- This is the PNL due to changes in interest rates.
- Column 7: Impact of Volatility --- This is the PNL due to changes in volatilities.
- Column 8: Impact of New Trades --- PNL from trades done on the current day.
- Column 9: Impact of Cancellation / Amendment - PNL from trades cancelled or changed on the current day.

ii. Methods of PNL Attribution

There are two methodologies for calculating PNL Explained, the 'Sensitivities' Method and the 'Revaluation' Method.

i. Sensitivities Method

The Sensitivities Method involves first calculating option sensitivities known as the Greeks because of the common practice of representing the sensitivities using Greek letters. For example, the delta of an option is the value an option changes due to a $0.01 move in the underlying commodity or equity/stock. To calculate 'Impact of Prices' the formula is

Impact of Prices = Option Delta * Price Move

So, if the price moves $0.05 and the option's delta is $100 then the 'Impact of Prices' is $500.

Since this method uses the Greeks (Delta, Gamma, Vega, Theta, etc.) and since many trading systems already calculate the Greeks, this method can be easier to implement than the revaluation method.

But the sensitivity method is inherently incapable of explaining P&L unless all first, second, and higher order sensitivities are calculated as well as all cross effects. However, calculating all sensitivities is not usually practical from a performance point of view.

ii. Revaluation Method

The Revaluation Method recalculates the value of a trade based on the current and the prior day's prices. The formula for Impact of Prices using the Revaluation Method is

Impact of Prices = (Trade Value using Today's Prices) - (Trade Value using Prior Day's Prices)

This method can be fully accurate, meaning there can be no explained since the revaluation method isn't subject to the limitations in accuracy of the sensitivities method as it is typically implemented. However, this does not allow for PNL to be attributed to second order effects.

The basic idea is very simple. You have a risk model that maps expected market movements into expected (portfolio) variation. So, what you do is, instead of using expected market movements, you use actual market movements and feed them into your risk model. The result is expected (portfolio) movement, i.e. P&L. This expected/theoretical P&L is then compared to the actual P&L. Ideally the difference between the two should be minimal (but this is never the case).

Attribution and risk management is inherently the same thing. If you can explain the majority of your daily, weekly or monthly P&L swings in your attribution, then you know you also have a good risk model. Put the other way, if your attribution cannot explain much of the P&L, then your risk model is probably very bad too.

The figure given below shows the process of PNL attribution:

This figure shows a template of PNL attribution report:


Total P&L
Total Profit and Loss
Top Level Explanatory Factors
Impact of Prices
Impact of Volatilities
Impact of Correlations
Impact of Amendments/ Changes
Impact of Interest Rates
Impact of FX
Impact of Time
New Trades
Unexplained
Detailed Explanatory Factors
Impact of Delta
Impact of Gamma
Impact of Cross Gamma
Impact of Vega
Impact of Vega Gamma
Impact of Cross Vega
Impact of Correlations
Impact of Correl Gamma
Impact of Cross Correl
Impact of Amendments
Impact of Cancelation
Impact of Option Exercise
Impact of etc...
Impact of Interest Rates
Impact of Convexity
Impact of FX
Impact of Time
New Trades
Unexplained

RISK MODEL VALIDATION

(Theory, Calculations and Practical Concepts)

I. Concept of Risk Model Validation

Financial assets can be divided into two categories. In the first category, we find the assets for which a price can be directly observed in the financial market place. These are the liquid assets for which there are either organized markets (e.g. Futures exchanges) or a liquid OTC market (e.g. interest rate swaps). For the vast majority of assets, however, price cannot be directly observed, but needs to be inferred from observable prices of related instruments.

This is typically the case for financial derivatives whose price is related to various features of the primary assets, depending on a model. This process is known as "marking-to-model", and involves both a mathematical algorithm and subjective components, thus exposing the process to estimation error. Beyond this generic observation, the notion of Model Risk has been interpreted in at least three manners.

- A first interpretation of Model Risk stems from the observation that various models can be calibrated to perfectly price a set of liquid instruments, but produce inconsistent estimates for an exotic product. If one accepts that there is one "true" model, then model risk refers to the risk of misspecification.

- A second interpretation focuses on the operational use of a model that is used not only to compute a price, but equally importantly to compute risk indicators for dynamic hedging. In a perfect world where the true process for each risk factor is known, and where hedge instruments are readily available, we know that to each derivative corresponds a dynamic replicating portfolio. Thus "model-risk" can be assessed by observing the hedging error, i.e. the discrepancy between the payoff of a derivative and the value of the replicating portfolio.

- Well publicized events in the banking industry have highlighted a third manifestation of Model Risk. When liquidity is low, how should a product be "marked to model" so as to minimize the risk of discrepancy when a transaction can finally be observed?

In simple terms, Model Risk is the risk of significant difference between mark to Model value of a financial instrument and its Market traded price.

In summary, Model Risk can lead to both mispricing and mismanagement of the hedging strategy. Mispricing clearly will have the most spectacular consequences, but mis hedging is an equally serious issue.

The importance of Model Risk has gradually emerged in the industry: in first-tier banks, Model Validation teams have been created as an independent power besides front-office trading/quant teams.

II. Principles of Model Validation

There are 6 basic principles of risk model validations which need to be considered and adhered to during any kind of validation exercise:

- Validation is fundamentally about assessing the predictive ability of an institution's risk estimates and the use of ratings in credit processes.
- The credit institution has primary responsibility for validation.
- Validation is an iterative process.
- There is no single validation method.
- Validation should encompass both quantitative and qualitative elements.
- Validation processes and outcomes should be subject to independent review.

III. Structure of Risk Models

The term *Model* refers to a quantitative method, system, or approach that applies statistical, economic, financial, or mathematical theories, techniques, and assumptions to process input data into quantitative estimates. A model consists of three components:

- An information input component, which delivers assumptions and data to the model;
- A processing component, which transforms inputs into estimates;
- A reporting component, which translates the estimates into useful business information.

Models meeting this definition might be used for analyzing business strategies, informing business decisions, identifying and measuring risks, valuing exposures, instruments or positions, conducting stress testing, assessing adequacy of capital, managing client assets, measuring compliance with internal limits, maintaining the formal control apparatus of the bank, or meeting financial or regulatory reporting requirements and issuing public disclosures. The definition of model also covers quantitative approaches whose inputs are partially or wholly qualitative or based on expert judgment, provided that the output is quantitative in nature.

Models are simplified representations of real-world relationships among observed characteristics, values, and events. Simplification is inevitable, due to the inherent complexity of those relationships, but also intentional, to focus attention on particular aspects considered to be most important for a given model application. Model quality can be measured in many ways: precision, accuracy, discriminatory power, robustness, stability, and reliability, to name a few. Models are never perfect, and the appropriate metrics of quality, and the effort that should be put into improving quality, depend on the situation.

IV. Model Risks

The use of models invariably presents model risk, which is the potential for adverse consequences from decisions based on incorrect or misused model outputs and reports. Model risk can lead to financial loss, poor business and strategic decision making, or damage to a bank's reputation. Model risk occurs primarily for two reasons:

- The model may have fundamental errors and may produce inaccurate outputs when viewed against the design objective and intended business uses. The mathematical calculation and quantification exercise underlying any model generally involves application of theory, choice of sample design and numerical routines, selection of inputs and estimation, and implementation in information systems. Errors can occur at any point from design through implementation. In addition, shortcuts, simplifications, or approximations used to manage complicated problems could compromise the integrity and reliability of outputs from those calculations. Finally, the quality of model outputs depends on the quality of input data and assumptions, and errors in inputs or incorrect assumptions will lead to inaccurate outputs.

- The model may be used incorrectly or inappropriately. Even a fundamentally sound model producing accurate outputs consistent with the design objective of the model may exhibit high model risk if it is misapplied or misused. Models by their nature are simplifications of reality, and real-world events may prove those simplifications inappropriate. This is even more of a concern if a model is used outside the environment for which it was designed.

  Banks may do this intentionally as they apply existing models to new products or markets, or inadvertently as market conditions or customer behavior changes. Decision makers need to understand the limitations of a model to avoid using it in ways that are not consistent with the original intent. Limitations come in part from weaknesses in the model due to its various shortcomings, approximations, and uncertainties. Limitations are also a consequence of assumptions underlying a model that may restrict the scope to a limited set of specific circumstances and situations.

V. Management of Model Risk

Model risk management begins with robust model development, implementation, and use. Another essential element is a sound model validation process. A third element is governance, which sets an effective framework with defined roles and responsibilities for clear communication of model limitations and assumptions, as well as the authority to restrict model usage.

Model risk management should include disciplined and knowledgeable development and implementation processes that are consistent with the situation and goals of the model user and with bank policy. Model development is not a straightforward or routine technical process. The experience and judgment of developers, as much as their technical knowledge, greatly influence the appropriate selection of inputs and processing components. The training and experience of developers exercising such judgment affects the extent of model risk. Moreover, the modeling exercise is often a multidisciplinary activity drawing on economics, finance, statistics, mathematics, and other fields. Models are employed in real-world markets and events and therefore should be tailored for specific applications and informed by business uses. In addition, a considerable amount of subjective judgment is exercised at various stages of model development, implementation, use, and validation. It is important for decision makers to recognize that this subjectivity elevates the importance of sound and comprehensive model risk management processes.

i. Model Development and Implementation

An effective development process begins with a clear statement of purpose to ensure that model development is aligned with the intended use. The design, theory, and logic underlying the model should be well documented and generally supported by published research and sound industry practice. The model methodologies and processing components that implement the theory, including the mathematical specification and the numerical techniques and approximations, should be explained in detail with particular attention to merits and limitations. Developers should ensure that the components work as intended, are appropriate for the intended business purpose, and are conceptually sound and mathematically and statistically correct. Comparison with alternative theories and approaches is a fundamental component of a sound modeling process.

The data and other information used to develop a model are of critical importance; there should be rigorous assessment of data quality and relevance, and appropriate documentation. Developers should be able to demonstrate that such data and information are suitable for the model and that they are consistent with the theory behind the approach and with the chosen methodology. If data proxies are used, they should be carefully identified, justified, and documented. If data and information are not representative of the bank's portfolio or other characteristics, or if assumptions are made to adjust the data and information, these factors should be properly tracked and analyzed so that users are aware of potential limitations. This is particularly important for external data and information (from a vendor or outside party), especially as they relate to new products, instruments, or activities.

An integral part of model development is testing, in which the various components of a model and its overall functioning are evaluated to determine whether the model is performing as intended. Model testing includes checking the model's accuracy, demonstrating that the model is robust and stable, assessing potential limitations, and evaluating the model's behavior over a range of input values. It should also assess the impact of assumptions and identify situations where the model performs poorly or becomes unreliable. Testing should be applied to actual circumstances under a variety of market conditions, including scenarios that are outside the range of ordinary expectations, and should encompass the variety of products or applications for which the model is intended. Extreme values for inputs should be evaluated to identify any boundaries of model effectiveness. The impact of model results on other models that rely on those results as inputs should also be evaluated. Included in testing activities should be the purpose, design, and execution of test plans, summary results with commentary and evaluation, and detailed analysis of informative samples. Testing activities should be appropriately documented.

The nature of testing and analysis will depend on the type of model and will be judged by different criteria depending on the context. For example, the appropriate statistical tests depend on specific distributional assumptions and the purpose of the model. Furthermore, in many cases statistical tests cannot unambiguously reject false hypotheses or accept true ones based on sample information. Different tests have different strengths and weaknesses under different conditions. Any single test is rarely sufficient, so banks should apply a variety of tests to develop a sound model.

Banks should ensure that the development of the more judgmental and qualitative aspects of their models is also sound. In some cases, banks may take statistical output from a model and modify it with judgmental or qualitative adjustments as part of model development. While such practices may be appropriate, banks should ensure that any such adjustments made as part of the development process are conducted in an appropriate and systematic manner, and are well documented.

Models typically are embedded in larger information systems that manage the flow of data from various sources into the model and handle the aggregation and reporting of model outcomes. Model calculations should be properly coordinated with the capabilities and requirements of information systems. Sound model risk management depends on substantial investment in supporting systems to ensure data and reporting integrity, together with controls and testing to ensure proper implementation of models, effective systems integration, and appropriate use.

ii. Model Use

Model use provides additional opportunity to test whether a model is functioning effectively and to assess its performance over time as conditions and model applications change. It can serve as a source of productive feedback and insights from a knowledgeable internal constituency with strong interest in having models that function well and reflect economic and business realities. Model users can provide valuable business insight during the development process. In addition, business managers affected by model outcomes may question the methods or assumptions underlying the models, particularly if the managers are significantly affected by and do not agree with the outcome. Such questioning can be healthy if it is constructive and causes model developers to explain and justify the assumptions and design of the models.

However, challenge from model users may be weak if the model does not materially affect their results, if the resulting changes in models are perceived to have adverse effects on the business line, or if change in general is regarded as expensive or difficult. User challenges also tend not to be comprehensive because they focus on aspects of models that have the most direct impact on the user's measured business performance or compensation, and thus may ignore other elements and applications of the models. Finally, such challenges tend to be asymmetric, because users are less likely to challenge an outcome that results in an advantage for them. Indeed, users may incorrectly believe that model risk is low simply because outcomes from model-based decisions appear favorable to the institution. Thus, the nature and motivation behind model users' input should be evaluated carefully, and banks should also solicit constructive suggestions and criticism from sources independent of the line of business using the model.

Reports used for business decision making play a critical role in model risk management. Such reports should be clear and comprehensible and take into account the fact that decision makers and modelers often come from quite different backgrounds and may interpret the contents in different ways. Reports that provide a range of estimates for different input-value scenarios and assumption values can give decision makers important indications of the model's accuracy, robustness, and stability as well as information on model limitations.

An understanding of model uncertainty and inaccuracy and a demonstration that the bank is accounting for them appropriately are important outcomes of effective model development, implementation, and use. Because they are by definition imperfect representations of reality, all models have some degree of uncertainty and inaccuracy. These can sometimes be quantified, for example, by an assessment of the potential impact of factors that are unobservable or not fully incorporated in the model, or by the confidence interval around a statistical model's point estimate. Indeed, using a range of outputs, rather than a simple point estimate, can be a useful way to signal model uncertainty and avoid spurious precision. At other times, only a qualitative assessment of model uncertainty and inaccuracy is possible. In either case, it can be prudent for banks to account for model uncertainty by explicitly adjusting model inputs or calculations to produce more severe or adverse model output in the interest of conservatism. Accounting for model

uncertainty can also include judgmental conservative adjustments to model output, placing less emphasis on that model's output, or ensuring that the model is only used when supplemented by other models or approaches.
While conservative use of models is prudent in general, banks should be careful in applying conservatism broadly or claiming to make conservative adjustments or add-ons to address model risk, because the impact of such conservatism in complex models may not be obvious or intuitive. Model aspects that appear conservative in one model may not be truly conservative compared with alternative methods. For example, simply picking an extreme point on a given modeled distribution may not be conservative if the distribution was misestimated or mis specified in the first place.

Furthermore, initially conservative assumptions may not remain conservative over time. Therefore, banks should justify and substantiate claims that model outputs are conservative with a definition and measurement of that conservatism that is communicated to model users. In some cases, sensitivity analysis or other types of stress testing can be used to demonstrate that a model is indeed conservative. Another way in which banks may choose to be conservative is to hold an additional cushion of capital to protect against potential losses associated with model risk. However, conservatism can become an impediment to proper model development and application if it is seen as a solution that dissuades the bank from making the effort to improve the model; in addition, excessive conservatism can lead model users to discount the model outputs.

VI. Model Validation Process

Robust model development, implementation, and use are important to model risk management. But it is not enough for model developers and users to understand and accept the model. Because model risk is ultimately borne by the bank as a whole, the bank should objectively assess model risk and the associated costs and benefits using a sound model-validation process.

Model validation is the set of processes and activities intended to verify that models are performing as expected, in line with their design objectives and business uses. Effective validation helps ensure that models are sound. It also identifies potential limitations and assumptions, and assesses their possible impact. As with other aspects of effective challenge, model validation should be performed by staff with appropriate incentives, competence, and influence.

All model components, including input, processing, and reporting, should be subject to validation; this applies equally to models developed in-house and to those purchased from or developed by vendors or consultants. The rigor and sophistication of validation should be commensurate with the bank's overall use of models, the complexity and materiality of its models, and the size and complexity of the bank's operations.

Validation involves a degree of independence from model development and use. Generally, validation should be done by people who are not responsible for development or use and do not have a stake in whether a model is determined to be valid. Independence is not an end in itself but rather helps ensure that incentives are aligned with the goals of model validation. While independence may be supported by separation of reporting lines, it should be judged by actions and outcomes, since there may be additional ways to ensure objectivity and prevent bias. As a practical matter, some validation work may be most effectively done by model developers and users; it is essential, however, that such validation work is subject to critical review by an independent party, who should conduct additional activities to ensure proper validation. Overall, the quality of the process is judged by the manner in which models are subject to critical review. This could be determined by evaluating the extent and clarity of documentation, the issues identified by objective parties, and the actions taken by management to address model issues.

In addition to independence, banks can support appropriate incentives in validation through compensation practices and performance evaluation standards that are tied directly to the quality of model validations and the degree of critical, unbiased review. In addition, corporate culture plays a role if it establishes support for objective thinking and encourages questioning and challenging of decisions.

Staff doing validation should have the requisite knowledge, skills, and expertise. A high level of technical expertise may be needed because of the complexity of many models, both in structure and in application. These staff also should have a significant degree of familiarity with the line of business using the model and the model's intended use. A model's developer is an important source of information but cannot be relied on as an objective or sole source on which to base an assessment of model quality.

Staff conducting validation work should have explicit authority to challenge developers and users and to elevate their findings, including issues and deficiencies. The individual or unit to whom those staff report should have sufficient influence or stature within the bank to ensure that any issues and deficiencies are appropriately addressed in a timely and substantive manner. Such influence can be reflected in reporting lines, title, rank, or designated responsibilities. Influence may be demonstrated by a pattern of actual instances in which models, or the use of models, have been appropriately changed as a result of validation.

The range and rigor of validation activities conducted prior to first use of a model should be in line with the potential risk presented by use of the model. If significant deficiencies are noted as a result of the validation process, use of the model should not be allowed or should be permitted only under very tight constraints until those issues are resolved. If the deficiencies are too severe to be addressed within the model's framework, the model should be rejected. If it is not feasible to conduct necessary validation activities prior to model use because of data paucity or other limitations, that fact should be documented and communicated in reports to users, senior management, and other relevant parties. In such cases, the uncertainty about the results that the model produces should be mitigated by other compensating controls. This is particularly applicable to new models and to the use of existing models in new applications.

Validation activities should continue on an ongoing b basis after a model goes into use, to track known model limitations and to identify any new ones. Validation is an important check on model use during periods of benign economic and financial conditions, when estimates of risk and potential loss can become overly optimistic, and when the data at hand may not fully reflect more stressed conditions. Ongoing validation activities help to ensure that changes in markets, products, exposures, activities, clients, or business practices do not create new model limitations. For example, if credit risk models do not incorporate underwriting changes in a timely manner, flawed and costly business decisions could be made before deterioration in model performance becomes apparent.

Banks should conduct a periodic review—at least annually but more frequently if warranted—of each model to determine whether it is working as intended and if the existing validation activities are sufficient. Such a determination could simply affirm previous validation work, suggest updates to previous validation activities, or call for additional validation activities. Material changes to models should also be subject to validation. It is generally good practice for banks to ensure that all models undergo the full validation process, as described in the following section, at some fixed interval, including updated documentation of all activities.

Effective model validation helps reduce model risk by identifying model errors, corrective actions, and appropriate use. It also provides an assessment of the reliability of a given model, based on its underlying assumptions, theory, and methods. In this way, it provides information about the source and extent of model risk. Validation also can reveal deterioration in model performance over time and can set thresholds for acceptable levels of error, through analysis of the distribution of outcomes around expected or predicted values. If outcomes fall consistently outside this acceptable range, then the models should be redeveloped.

The Basel Committee on Banking Supervision issues recommendations on controlling model and operational risk. The elements of a "rigorous model validation" are described as follows:

- The model's theoretical soundness and mathematical integrity.
- The appropriateness of model assumptions, including consistency with market practices and consistency with relevant contractual terms of transactions.
- Sensitivity analysis performed to assess the impact of variations in model parameters on fair value, including under stress conditions.

- Benchmarking of the valuation result with the observed market price at the time of valuation or independent benchmark model.

VII. Model Validation Framework

An effective validation framework should include three core elements:

- Evaluation of conceptual soundness, including developmental evidence.
- Ongoing monitoring, including process verification and benchmarking.
- Outcomes analysis, including back-testing.

i. Evaluation of Conceptual Soundness

This element involves assessing the quality of the model design and construction. It entails review of documentation and empirical evidence supporting the methods used and variables selected for the model. Documentation and testing should convey an understanding of model limitations and assumptions. Validation should ensure that judgment exercised in model design and construction is well informed, carefully considered, and consistent with published research and with sound industry practice. Developmental evidence should be reviewed before a model goes into use and also as part of the ongoing validation process, in particular whenever there is a material change in the model.

A sound development process will produce documented evidence in support of all model choices, including the overall theoretical construction, key assumptions, data, and specific mathematical calculations. As part of model validation, those model aspects should be subjected to critical analysis by both evaluating the quality and extent of developmental evidence and conducting additional analysis and testing as necessary. Comparison to alternative theories and approaches should be included. Key assumptions and the choice of variables should be assessed, with analysis of their impact on model outputs and particular focus on any potential limitations. The relevance of the data used to build the model should be evaluated to ensure that it is reasonably representative of the bank's portfolio or market conditions, depending on the type of model. This is an especially important exercise when a bank uses external data or the model is used for new products or activities.

Where appropriate to the particular model, banks should employ sensitivity analysis in model development and validation to check the impact of small changes in inputs and parameter values on model outputs to make sure they fall within an expected range. Unexpectedly large changes in outputs in response to small changes in inputs can indicate an unstable model.

Varying several inputs simultaneously as part of sensitivity analysis can provide evidence of unexpected interactions, particularly if the interactions are complex and not intuitively clear. Banks benefit from conducting model stress testing to check performance over a wide range of inputs and parameter values, including extreme values, to verify that the model is robust. Such testing helps establish the boundaries of model performance by identifying the acceptable range of inputs as well as conditions under which the model may become unstable or inaccurate.

Management should have a clear plan for using the results of sensitivity analysis and other quantitative testing. If testing indicates that the model may be inaccurate or unstable in some circumstances, management should consider modifying certain model properties, putting less reliance on its outputs, placing limits on model use, or developing a new approach.

Qualitative information and judgment used in model development should be evaluated, including the logic, judgment, and types of information used, to establish the conceptual soundness of the model and set appropriate conditions for its use. The validation process should ensure that qualitative, judgmental assessments are conducted in an appropriate and systematic manner, are well supported, and are documented.

ii. Ongoing Monitoring

The second core element of the validation process is ongoing monitoring. Such monitoring confirms that the model is appropriately implemented and is being used and is performing as intended.

Ongoing monitoring is essential to evaluate whether changes in products, exposures, activities, clients, or market conditions necessitate adjustment, redevelopment, or replacement of the model and to verify that any extension of the model beyond its original scope is valid. Any model limitations identified in the development stage should be regularly assessed over time, as part of ongoing monitoring. Monitoring begins when a model is first implemented in production systems for actual business use. This monitoring should continue periodically over time, with a frequency appropriate to the nature of the model, the availability of new data or modeling approaches, and the magnitude of the risk involved. Banks should design a program of ongoing testing and evaluation of model performance along with procedures for responding to any problems that appear. This program should include process verification and benchmarking.

Process verification checks that all model components are functioning as designed. It includes verifying that internal and external data inputs continue to be accurate, complete, consistent with model purpose and design, and of the highest quality available. Computer code implementing the model should be subject to rigorous quality and change control procedures to ensure that the code is correct, that it cannot be altered except by approved parties, and that all changes are logged and can be audited. System integration can be a challenge and deserves special attention because the model processing component often draws from various sources of data, processes large amounts of data, and then feeds into multiple data repositories and reporting systems. User-developed applications, such as spreadsheets or ad hoc database applications used to generate quantitative estimates are particularly prone to model risk. As the content or composition of information changes over time, systems may need to be updated to reflect any changes in the data or its use. Reports derived from model outputs should be reviewed as part of validation to verify that they are accurate, complete, and informative, and that they contain appropriate indicators of model performance and limitations.

Many of the tests employed as part of model development should be included in ongoing monitoring and be conducted on a regular basis to incorporate additional information as it becomes available. New empirical evidence or theoretical research may suggest the need to modify or even replace original methods. Analysis of the integrity and applicability of internal and external information sources, including information provided by third-party vendors, should be performed regularly.

Sensitivity analysis and other checks for robustness and stability should likewise be repeated periodically. They can be as useful during ongoing monitoring as they are during model development. If models only work well for certain ranges of input values, market conditions, or other factors, they should be monitored to identify situations where these constraints are approached or exceeded.

Ongoing monitoring should include the analysis of overrides with appropriate documentation. In the use of virtually any model, there will be cases where model output is ignored, altered, or reversed based on the expert judgment of model users. Such overrides are an indication that, in some respect, the model is not performing as intended or has limitations. Banks should evaluate the reasons for overrides and track and analyze override performance. If the rate of overrides is high, or if the override process consistently improves model performance, it is often a sign that the underlying model needs revision or redevelopment.

Benchmarking is the comparison of a given model's inputs and outputs to estimates from alternative internal or external data or models. It can be incorporated in model development as well as in ongoing monitoring. For credit risk models, examples of benchmarks include models from vendor firms or industry consortia and data from retail credit bureaus. Pricing models for securities and derivatives often can be compared with alternative models that are more accurate or comprehensive but also too time consuming to run on a daily basis. Whatever the source, benchmark models should be rigorous and benchmark data should be accurate and complete to ensure a reasonable comparison.

Discrepancies between the model output and benchmarks should trigger investigation into the sources and degree of the differences, and examination of whether they are within an expected or appropriate range given the nature of the comparison. The results of that analysis may suggest revisions to the model. However, differences do not necessarily indicate that the model is in error. The benchmark itself is an alternative prediction, and the differences may be due to the different data or methods used. If the model and the benchmark match well, that is evidence in favor of the model, but it should be interpreted with caution so the bank does not get a false degree of comfort.

iii. Outcomes Analysis

The third core element of the validation process is outcomes analysis, a comparison of model outputs to corresponding actual outcomes. The precise nature of the comparison depends on the objectives of a model, and might include an assessment of the accuracy of estimates or forecasts, an evaluation of rank-ordering ability, or other appropriate tests. In all cases, such comparisons help to evaluate model performance, by establishing expected ranges for those actual outcomes in relation to the intended objectives and assessing the reasons for observed variation between the two. If outcomes analysis produces evidence of poor performance, the bank should take action to address those issues. Outcomes analysis typically relies on statistical tests or other quantitative measures. It can also include expert judgment to check the intuition behind the outcomes and confirm that the results make sense. When a model itself relies on expert judgment, quantitative outcomes analysis helps to evaluate the quality of that judgment. Outcomes analysis should be conducted on an ongoing basis to test whether the model continues to perform in line with design objectives and business uses.

A variety of quantitative and qualitative testing and analytical techniques can be used in outcomes analysis. The choice of technique should be based on the model's methodology, its complexity, data availability, and the magnitude of potential model risk to the bank. Outcomes analysis should involve a range of tests because any individual test will have weaknesses. For example, some tests are better at checking a model's ability to rank-order or segment observations on a relative basis, whereas others are better at checking absolute forecast accuracy. Tests should be designed for each situation, as not all will be effective or feasible in every circumstance, and attention should be paid to choosing the appropriate type of outcomes analysis for a particular model.

Models are regularly adjusted to take into account new data or techniques, or because of deterioration in performance. Parallel outcomes analysis, under which both the original and adjusted models' forecasts are tested against realized outcomes, provides an important test of such model adjustments. If the adjusted model does not outperform the original model, developers, users, and reviewers should realize that additional changes—or even a wholesale redesign—are likely necessary before the adjusted model replaces the original one.

Back-testing is one form of outcomes analysis; specifically, it involves the comparison of actual outcomes with model forecasts during a sample time period not used in model development and at an observation frequency that matches the forecast horizon or performance window of the model. The comparison is generally done using expected ranges or statistical confidence intervals around the model forecasts. When outcomes fall outside those intervals, the bank should analyze the discrepancies and investigate the causes that are significant in terms of magnitude or frequency. The objective of the analysis is to determine whether differences stem from the omission of material factors from the model, whether they arise from errors with regard to other aspects of model specification such as interaction terms or assumptions of linearity, or whether they are purely random and thus consistent with acceptable model performance. Analysis of in-sample fit and of model performance in holdout samples (data set aside and not used to estimate the original model) are important parts of model development but are not substitutes for back-testing.

A well-known example of back-testing is the evaluation of value-at-risk (VaR), in which actual profit and loss is compared with a model forecast loss distribution. Significant deviation in expected versus actual performance and unexplained volatility in the profits and losses of trading activities may indicate that hedging and pricing relationships are not adequately measured by a given approach. Along with measuring the frequency of losses in excess of a single VaR percentile estimator, banks should use other tests, such as assessing any clustering of exceptions and checking the distribution of losses against other estimated percentiles.

Analysis of the results of even high-quality and well-designed back-testing can pose challenges, since it is not a straightforward, mechanical process that always produces unambiguous results. The purpose is to test the model, not individual forecast values. Back-testing may entail analysis of a large number of forecasts over different conditions at a point in time or over multiple time periods. Statistical testing is essential in such cases, yet such testing can pose challenges in both the choice of appropriate tests and the interpretation of results; banks should support and document both the choice of tests and the interpretation of results.

Models with long forecast horizons should be back-tested, but given the amount of time it would take to accumulate the necessary data, that testing should be supplemented by evaluation over shorter periods. Banks should employ outcomes analysis consisting of "early warning" metrics designed to measure performance beginning very shortly after model introduction and trend analysis of performance over time. These outcomes analysis tools are not substitutes for back-testing, which should still be performed over the longer time period, but rather very important complements.

Outcomes analysis and the other elements of the validation process may reveal significant errors or inaccuracies in model development or outcomes that consistently fall outside the bank's predetermined thresholds of acceptability. In such cases, model adjustment, recalibration, or redevelopment is warranted. Adjustments and recalibration should be governed by the principle of conservatism and should undergo independent review.

Material changes in model structure or technique, and all model redevelopment, should be subject to validation activities of appropriate range and rigor before implementation. At times banks may have a limited ability to use key model validation tools like back-testing or sensitivity analysis for various reasons, such as lack of data or of price observability. In those cases, even more attention should be paid to the model's limitations when considering the appropriateness of model usage, and senior management should be fully informed of those limitations when using the models for decision making. Such scrutiny should be applied to individual models and models in the aggregate.

BASEL ACCORD

(Introduction, Structure and Concept)

The Basel Accords refer to the banking supervision Accords (recommendations on banking regulations)—Basel I, Basel II and Basel III—issued by the Basel Committee on Banking Supervision (BCBS). They are called the Basel Accords as the BCBS maintains its secretariat at the Bank for International Settlements in Basel, Switzerland and the committee normally meets there.

Formerly, the Basel Committee consisted of representatives from central banks and regulatory authorities of the Group of Ten countries plus Luxembourg and Spain. Since 2009, all of the other G-20 major economies are represented, as well as some other major banking locales such as Hong Kong and Singapore.

The committee does not have the authority to enforce recommendations, although most member countries as well as some other countries tend to implement the Committee's policies. This means that recommendations are enforced through national (or EU-wide) laws and regulations, rather than as a result of the committee's recommendations - thus some time may pass between recommendations and implementation as law at the national level.

The Committee was formed in response to the messy liquidation of a Cologne-based bank (Herstatt Bank) in 1974. On 26 June 1974, a number of banks had released Deutsche Mark (German Mark) to the Bank Herstatt in exchange for dollar payments deliverable in New York. On account of differences in the time zones, there was a lag in the dollar payment to the counter-party banks, and during this gap, and before the dollar payments could be effected in New York, the Bank Herstatt was liquidated by German regulators. The counterparty banks did not receive their USD payments.

This incident prompted the G-10 nations to form towards the end of 1974, the Basel Committee on Banking Supervision, under the auspices of the Bank of International Settlements (BIS) located in Basel, Switzerland. Over time, the focus of the committee has evolved, embracing initiatives designed to:

- Define roles of regulators in cross-jurisdictional situations;
- Ensure that international banks or bank holding companies do not escape comprehensive supervision by a "home" regulatory authority;
- Promote uniform capital requirements so banks from different countries may compete with one another on a "level playing field."

The Basel Committee's does not have legislative authority, but participant countries are implicitly bound to implement its recommendations. Usually, the committee has allowed for some flexibility in how local authorities implement recommendations, so national laws vary.

In 1988, the Basel Committee proposed a set of minimal capital requirements for banks. These became law in G-10 countries in 1992, with Japanese banks permitted an extended transition period. The requirements have come to be known as the 1988 Basel Accord.

I. Basel I – 1988 Accord

Basel I is the round of deliberations by central bankers from around the world, and in 1988, the Basel Committee (BCBS) in Basel, Switzerland, published a set of minimal capital requirements for banks. This is also known as the 1988 Basel Accord, and was enforced by law in the Group of Ten (G-10) countries in 1992 . Basel I is now widely viewed as outmoded.

The 1988 Basel Accord primarily addressed banking in the sense of deposit taking and lending (commercial banking under US law), so its focus was credit risk. Banks were subject to an 8% capital requirement. Specifically, they would calculate metrics for:

- Capital Risk
- Credit Risk

The requirement under the 1988 Basel Accord was that:

Capital / Credit Risk > 8%

A bank's capital was defined as comprising two tiers. Tier 1 or Core Capital included the book value of common stock, non-cumulative perpetual preferred stock and published reserves from post-tax retained earnings. Tier 2 or Supplementary Capital was deemed of lower quality. It included, subject to various conditions, general loan loss reserves, long-term subordinated debt and cumulative and/or redeemable preferred stock. A maximum of 50% of a bank's capital could comprise tier 2 capital.

Credit risk was calculated as the sum of risk-weighted asset values. Generally, G-10 government debt was weighted 0%, G-10 bank debt was weighted 20%, and other debt, including corporate debt and the debt of non-G-10 governments, was weighted 100%. Additional rules applied to mortgages, local government debt in G-10 countries, and contingent obligations, such as letters of credit or derivatives.

In the early 1990s, the Basel Committee decided to update the 1988 accord to include bank capital requirements for market risk. This had implications for non-bank securities firms. Because of the fundamental differences between banks and securities firms, the initiative soon ran into trouble.

In April 1993, following the failure of the Basel initiative, the Basel Committee released a package of proposed amendments to the 1988 accord. Primarily, these proposed minimum capital requirements for banks' market risk. Under this amendment Banks were required to identify a trading book and hold capital for trading book market risks and organization-wide foreign exchange exposures. Capital charges for the trading book were based upon a crude value-at-risk (VaR) measure loosely consistent with a 10-day 95% VaR metric. In addition to capital for credit risk, banks were required to hold capital equal to the calculated VaR. If we define market risk as VaR/8%, the proposed amendment required that banks hold capital such that:

Capital / Credit Risk + Market Risk > 8%

The proposal also liberalized the definition of capital by adding a third tier. Tier 3 capital comprised short-term subordinated debt, but it could only be used to cover market risk.

The committee received numerous comments on this proposal. Commentators perceived the crude VaR measure as a step backwards. Many banks were already using proprietary VaR measures. Most of these modeled diversification effects, and some recognized portfolio non-linearities. Commentators wondered if, by embracing a crude VaR measure, regulators might stifle innovation in risk measurement technology.

In April 1995, the Basel Committee released a revised proposal. This made a number of changes, including the extension of market risk capital requirements to cover organization-wide commodities exposures. An important provision allowed banks to use either a regulatory building-block VaR measure or their own proprietary VaR measure for computing capital requirements. Use of a proprietary measure required approval of regulators. A bank would have to have an independent risk management function and satisfy regulators that it was following acceptable risk management practices. Regulators would also need to be satisfied that the proprietary VaR measure was sound.

Proprietary measures would need to support a 10-day 99% VaR metric and be able to address the non-linear exposures of options. Diversification effects could be recognized within broad asset categories—fixed income, equity, foreign exchange and commodities—but not across asset categories. Market risk capital requirements were set equal to the greater of:

- The previous day's VaR, or
- The average VaR over the previous sixty business days, multiplied by a factor of at least 3.

The original VaR measure which was now called the "standardized" measure was changed modestly from the 1993 proposal. It may reasonably be interpreted as still reflecting a 10-day 95% VaR metric. Extra capital charges were added in an attempt to recognize non-linear exposures.

The Basel Committee's new proposal was adopted in 1996 as an amendment to the 1988 accord. It is known as the 1996 amendment. It went into effect in 1998.

By this time, shortcomings with the original accord's treatment of credit risk were becoming evident. The simple system of risk weightings provided an incentive for banks to hold the 0% risk-weighted debt of G-10 governments (a fact viewed with some cynicism, since those same governments were largely responsible for the original accord). However, such debt tended to be unprofitable. Far more profitable for banks was corporate debt, which was weighted 100%. With all corporate debt being weighted equally, it made sense for banks to hold the most risky corporate debt. Higher quality corporate debt incurred exactly the same capital charges but was less profitable.

During this period, markets for credit derivatives and securitizations grew explosively. It was an open secret that banks were employing these to take advantage of shortcomings in the 1988 Accord's crude system of risk weights. This practice is called regulatory arbitrage.

Another issue during this period was operational risk. Operational risk poses significant risk for banks. It includes a variety of contingencies including fraud, which is routinely a factor in bank failures. Neither the original Basel Accord nor the 1996 Amendment required capital for operational risk.

II. Basel II

In January 1999, the Basel Committee proposed a new capital accord, which has come to be known as Basel II. There followed an extensive consultative period, with the committee releasing additional proposals for consultation in January 2001 and April 2003. It also conducted three quantitative impact studies to assess those proposals. The finalized Basel II Accord was released in June 2004.

Basel II is the second of the Basel Accords, (now extended and effectively superseded by Basel III), which are recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision.

Basel II, initially published in June 2004, was intended to create an international standard for banking regulators to control how much capital banks need to put aside to guard against the types of financial and operational risks banks (and the whole economy) face. One focus was to maintain sufficient consistency of regulations so that this does not become a source of competitive inequality amongst internationally active banks. Advocates of Basel II believed that such an international standard could help protect the international financial system from the types of problems that might arise should a major bank or a series of banks collapse. In theory, Basel II attempted to accomplish this by setting up risk and capital management requirements designed to ensure that a bank has adequate capital for the risk the bank exposes itself to through its lending and investment practices. Generally speaking, these rules mean that the greater risk to which the bank is exposed, the greater the amount of capital the bank needs to hold to safeguard its solvency and overall economic stability.

1. Structure of Basel II

Originally, it was planned that Basel II would be based on three pillars:

- Minimum Capital Requirements,
- Supervisory Review, and
- Market Discipline.

However, the final accord relied primarily on minimal capital requirements with only brief, largely aspirational specifications of the second and third pillars.

Generally, Basel II retains the definition of bank capital and the market risk provisions of the 1996 Amendment. It largely replaces the old treatment of credit risk, and it requires capital for operational risk.

The Basel I accord dealt with only parts of each of these pillars. For example: with respect to the first Basel II pillar, only one risk, credit risk, was dealt with in a simple manner while market risk was an afterthought; operational risk was not dealt with at all.

With some juggling, the basic capital requirement for banks might be expressed as:

Capital / Credit Risk + Market Risk + Operational Risk > 8%

i. First Pillar – Capital Requirements

The first pillar deals with maintenance of regulatory capital calculated for three major components of risk that a bank faces: credit risk, operational risk, and market risk. Other risks are not considered fully quantifiable at this stage.

The credit risk component can be calculated in three different ways of varying degree of sophistication, namely standardized approach, Foundation IRB and Advanced IRB. IRB stands for "Internal Rating-Based Approach".

For operational risk, there are three different approaches - basic indicator approach or BIA, standardized approach or STA, and the internal measurement approach (an advanced form of which is the advanced measurement approach or AMA).

For market risk the preferred approach is VaR (value at risk).

As the Basel 2 recommendations are phased in by the banking industry it will move from standardized requirements to more refined and specific requirements that have been developed for each risk category by each individual bank. The upside for banks that do develop their own bespoke risk measurement systems is that they will be rewarded with potentially lower risk capital requirements. In future there will be closer links between the concepts of economic profit and regulatory capital.

Credit Risk can be calculated by using one of three approaches:

1. Standardized Approach
2. Foundation IRB
3. Advanced IRB Approach

The standardized approach sets out specific risk weights for certain types of credit risk. The standard risk weight categories used under Basel 1 were 0% for government bonds, 20% for exposures to OECD Banks, 50% for first line residential mortgages and 100% weighting on consumer loans and unsecured commercial loans. Basel II introduced a new 150% weighting for borrowers with lower credit ratings. The minimum capital required remained at 8% of risk weighted assets, with Tier 1 capital making up not less than half of this amount.

Banks that decide to adopt the standardized ratings approach must rely on the ratings generated by external agencies. Certain banks used the IRB approach as a result.

ii. Second Pillar – Supervisory Review

The second pillar deals with the regulatory response to the first pillar, giving regulators much improved 'tools' over those available to them under Basel I. It also provides a framework for dealing with all the other risks a bank may face, such as systemic risk, pension risk, concentration risk, strategic risk, reputational risk, liquidity risk and legal risk, which the accord combines under the title of residual risk. It gives banks a power to review their risk management system.

Internal Capital Adequacy Assessment Process (ICAAP) is the result of Pillar II of Basel II accords.

iii. Third Pillar – Disclosure Requirements

This pillar aims to complement the minimum capital requirements and supervisory review process by developing a set of disclosure requirements which will allow the market participants to gauge the capital adequacy of an institution.

Market discipline supplements regulation as sharing of information facilitates assessment of the bank by others including investors, analysts, customers, other banks and rating agencies which leads to good corporate governance. The aim of pillar 3 is to allow market discipline to operate by requiring institutions to disclose details on the scope of application, capital, risk exposures, risk assessment processes and the capital adequacy of the institution. It must be consistent with how the senior management including the board assess and manage the risks of the institution.

When market participants have a sufficient understanding of a bank's activities and the controls it has in place to manage its exposures, they are better able to distinguish between banking organizations so that they can reward those that manage their risks prudently and penalize those that do not.

These disclosures are required to be made at least twice a year, except qualitative disclosures providing a summary of the general risk management objectives and policies which can be made annually. Institutions are also required to create a formal policy on what will be disclosed, controls around them along with the validation and frequency of these disclosures. In general, the disclosures under Pillar 3 apply to the top consolidated level of the banking group to which the Basel II framework applies.

The 2008 financial crisis forced numerous banks around the world to seek government bailouts. Due to delays, Basel II had been only partially implemented, but that was little excuse. The Basel approach to bank regulation had failed catastrophically. Regulators scrambled to cobble together enhanced capital standards, largely within the Basel II framework. These increased required capital levels and improved the quality of assets that would be considered capital. Tier 3 capital was eliminated. Regulators also introduced new requirements relating to bank liquidity and bank leverage. Extra capital charges apply to "systemically important" (i.e. "too big to fail") financial institutions. The new regime, called Basel III, has a gradual phase-in period extending through 2019.

III. Basel III

This, the third of the Basel Accords (see Basel I, Basel II) was developed in a response to the deficiencies in financial regulation revealed by the late-2000s financial crisis. Basel III strengthens bank capital requirements and introduces new regulatory requirements on bank liquidity and bank leverage. It is estimated that the implementation of Basel III will decrease annual GDP growth by 0.05 to 0.15 percentage point. Outside the banking industry itself, criticism was muted. Bank directors would be required to know market liquidity conditions for major asset holdings, to strengthen accountability for any major losses.

Basel III will require banks to hold 4.5% of common equity (up from 2% in Basel II) and 6% of Tier I capital (up from 4% in Basel II) of risk-weighted assets (RWA). Basel III also introduces additional capital buffers,

- Mandatory capital conservation buffer of 2.5% and
- Discretionary countercyclical buffer, which allows national regulators to require up to another 2.5% of capital during periods of high credit growth.

In addition, Basel III introduces a minimum 3% leverage ratio and two required liquidity ratios. The Liquidity Coverage Ratio requires a bank to hold sufficient high-quality liquid assets to cover its total net cash flows over 30 days; the Net Stable Funding Ratio requires the available amount of stable funding to exceed the required amount of stable funding over a one-year period of extended stress.

1. Structure of Basel III

First, the quality, consistency, and transparency of the capital base will be raised.

- Tier 1 capital: the predominant form of Tier 1 capital must be common shares and retained earnings.
- Tier 2 capital instruments will be harmonized.
- Tier 3 capital will be eliminated.

Second, the risk coverage of the capital framework will be strengthened.

- Promote more integrated management of market and counterparty credit risk.
- Add the CVA (credit valuation adjustment)-risk due to deterioration in counterparty's credit rating.
- Strengthen the capital requirements for counterparty credit exposures arising from banks' derivatives, repo and securities financing transactions.
- Raise the capital buffers backing these exposures.
- Reduce procyclicality.
- Provide additional incentives to move OTC derivative contracts to central counterparties.
- Provide incentives to strengthen the risk management of counterparty credit exposures.
- Raise counterparty credit risk management standards by including wrong-way risk.

Third, the Committee will introduce a leverage ratio as a supplementary measure to the Basel II risk-based framework.

- Put a floor under the build-up of leverage in the banking sector.
- Introduce additional safeguards against model risk and measurement error by supplementing the risk-based measure with a simpler measure that is based on gross exposures.

Fourth, the Committee is introducing a series of measures to promote the buildup of capital buffers in good times that can be drawn upon in periods of stress ("Reducing procyclicality and promoting countercyclical buffers").

- Dampen any excess cyclicality of the minimum capital requirement.
- Promote more forward-looking provisions.
- Conserve capital to build buffers at individual banks and the banking sector that can be used in stress.
- Requirement to use long term data horizons to estimate probabilities of default downturn loss-given-default estimates, recommended in Basel II, to become mandatory
- Improved calibration of the risk functions, which convert loss estimates into regulatory capital requirements.
- Banks must conduct stress tests that include widening credit spreads in recessionary scenarios.
- Advocating a change in the accounting standards towards an expected loss (EL) approach (usually, EL amount: = LGD*PD*EAD).

Fifth, the Committee is introducing a global minimum liquidity standard for internationally active banks that includes a 30-day liquidity coverage ratio requirement underpinned by a longer-term structural liquidity ratio called the Net Stable Funding Ratio.

The Committee also is reviewing the need for additional capital, liquidity or other supervisory measures to reduce the externalities created by systemically important institutions.

As on Sept 2010, Proposed Basel III norms ask for ratios as: 7-9.5%(4.5% +2.5%(conservation buffer) + 0-2.5%(seasonal buffer)) for Common equity and 8.5-11% for tier 1 cap and 10.5 to 13 for total capital.

IV. Analysis of Basel Accord and Its Implementation

1. Introduction

The revised Basel Accord (Basel II, replacing the original Basel Accord of 1988 (Basel I)) has been implemented throughout Europe with effect from 1 January 2007. It arrives at a time when bank capital is an area of topical interest given recent market events in the US and Europe. The intention of Basel II is to create a better framework for regulating bank capital. One of the main criticisms of Basel I was lack of sensitivity to credit risk. Risk weighting of credit exposures under Basel I depended on the category of counterparty, rather than its credit quality.

Thus, sovereign bonds were 0% risk weighted while all corporate loans were 100% risk weighted. This created arbitrage opportunities for maximizing return on capital by disposing of more expensive exposures to highly-rated corporates and acquiring cheaper exposures to lower-rated sovereigns. It also created perverse incentives – for example, the cost of capital associated with secured lending to a highly-rated corporate and unsecured lending to an unrated corporate was the same, effectively creating a regulatory incentive for banks to lend to more risky counterparties.

Clearly, the regulatory framework for risk management was inadequate. To ensure their capital adequacy, many sophisticated banks used their own internal risk management practices and, in particular, collation of historical loss data and internal rating of their counterparties on the basis of that data. With the rapid development of international banking at the end of the 1990s, it became necessary to create a regulatory framework for evaluating credit risks that would continue to promote safety and soundness in the financial system and encourage banks to develop and rely on sound lending and credit risk management practices. It was with this idea in mind that an internal ratings-based approach (the IRB) was created as part of Basel II.

It is expected that the IRB, which relies heavily upon a bank's internal assessment of its counterparties and exposures, will accurately align capital requirements with the intrinsic amount of credit risk and, consequently, may produce lower overall capital requirements. Only very large banks will be able to meet the requirements of the IRB. Others will use the alternative standardised approach, which is an improved version of Basel I.

Whether Basel II can achieve its wider goals of safety and soundness in the financial system is an open question. However, the IRB is undoubtedly more sensitive than the previous regime to the drivers of credit risks and economic losses. It encourages banks to improve their internal risk management practices. It is also complex. Some aspects of it require an appreciation of advanced mathematics.

2. IRB Components

The concept of expected and unexpected losses plays an important role in the economic foundation of the IRB. Whereas a bank cannot predict in advance what losses it will suffer over a given period, it can forecast the average level of credit losses. Expected losses (EL) are those within the average level of reasonably foreseeable credit losses. Unexpected losses (UL) relate to potentially large losses that occur infrequently. UL represent losses above the average level of reasonably foreseeable credit losses.

To prevent insolvency, a bank must have sufficient financial resources (i.e. capital, provisions and write offs) to cover the total of EL and UL. EL is generally regarded as costs of a banking business. Banks that adopt the IRB (IRB banks) must evaluate EL and factor them in when pricing their credit exposures and through provisioning and write-offs. Any shortfall between banks' actual provisions and EL must be deducted equally from Tier 1 capital (broadly, equity) and Tier 2 capital (broadly, subordinated debt), and any excess may be included in Tier 2 capital subject to a cap. UL must be covered in capital requirements.

i. Expected and Unexpected Loss

EL is calculated using three risk parameters: probability of default (PD), loss given default (LGD) and exposure at default (EAD) – estimated on an exposure-specific basis or, in the case of retail exposures, on a pool basis. The same risk parameters are used to calculate UL and, therefore, capital requirements. Depending upon which credit risk evaluation methodology IRB bank adopts, it may use its internal risk models to generate these risk parameters.

The IRB offers two credit risk evaluation methodologies: the foundation IRB (the FIRB) and the advanced IRB (the AIRB), the latter which only became available on 1 January 2008. Under both the FIRB and the AIRB, banks provide their regulators with an internal estimate of PD. Banks that adopt the FIRB (FIRB banks) have the other components set by their regulators. Banks that adopt the AIRB (AIRB banks) calculate all of their risk parameters (PD, LGD, EAD and the effective maturity (M) of exposures) using their internal models. In providing estimates of PD, LGD, EAD and M (as applicable), an IRB bank may rely on long-run data derived from its own experience, or from external sources, provided the bank can demonstrate the relevance of such data to its experience. In practical terms, IRB banks will be required to develop and implement a reliable process that enables them to collect, store and utilize loss statistics over a long period of time.

ii. Probability of Default

PD is the probability of an obligor defaulting on its contractual obligations within one year. Different banks have different approaches to defining "default". One of the greater challenges facing IRB banks is, therefore, to verify their historic loan performance information against the definition of "default" used by the regulator.

Under the IRB regime, a default occurs when, broadly:

- A bank considers that the obligor is unlikely to pay its credit obligations to the banking group in full (the IRB suggests certain cases where a bank may take such view); or
- The obligor's payment is more than 90 days overdue (for commercial counterparties) or up to 180 days overdue (for retail exposures) on any material credit obligation to the banking group.

Each estimate of PD must represent a conservative view of a long-run average PD for each obligor grade. For corporate and bank exposures, PD is subject to a floor of 0.03%. Banks must justify their PD estimates with sufficient historical experience and empirical evidence. Risk management processes and ratings upon which estimates are made will be subject to rigorous supervision and extensive recognition requirements.

iii. Loss Given Default and Exposure at Default

LGD is the estimate of loss that a bank will incur if its obligor defaults. EAD is the amount the obligor owes at the time of default. In contrast with PD, LGD is a facility-specific risk parameter that takes into account specific features of the relevant transaction (e.g. collateral, subordination, etc.). It must be based on a conservative view of long-run averages. EAD is also facility specific, which in most cases will be the nominal amount of the facility. For facilities that have undrawn commitment (e.g. revolving loans), EAD will include an estimate of future lending before default.

Assessment of LGD and EAD depends on the particular IRB methodology adopted. FIRB banks must use conservative standard supervisory rules, which determine the level of LGD and EAD based upon the characteristics of the relevant transaction including the presence and type of collateral or subordination. For example, unsecured corporate, bank and sovereign exposures are assigned a 45% LGD. Subordinated claims on similar asset classes are assigned a 75% LGD.

AIRB banks determine for themselves the appropriate LGD and EAD for each exposure, but are required to do so only on the basis of robust data analysis, which is capable of being validated both internally and by the supervisory authority. LGD and EAD assessment under the AIRB allows banks to take into account a wider set of transaction features (e.g. product type, collateral, etc.) as well as borrower characteristics. AIRB banks will be subject to more stringent minimum requirements in relation to the integrity and reliability of their estimates than those requirements applicable to FIRB banks.

iv. Maturity

M is the remaining economic maturity of an exposure. Determination of M also depends on the adopted IRB methodology. FIRB banks are required to assign M of 2.5 years, except for exposures arising from repo or securities lending transactions for which M of six months is assigned. AIRB banks calculate facility specific M on the basis of prescribed formulas, subject to a one-year floor and a five-year ceiling.

v. Credit Conversion Factor

Off-balance-sheet items are treated as undrawn but committed obligations. They are evaluated as the full amount of the undrawn commitment multiplied by a credit conversion factor (CCF). As with the other risk parameters, determination of CCF depends on the adopted IRB methodology. FIRB banks use CCFs provided by their regulators.

AIRB banks calculate their own CCFs.

2. Reassessment of Credit Risk

Given that risk parameters of an exposure fluctuate during the life of the exposure, credit risks associated with every exposure must be reassessed at least annually. Certain high-risk exposures must be reassessed more frequently. Banks must also reassess risk parameters of an exposure whenever they acquire new information relevant to that exposure. This may present a new challenge for banks that were not accustomed to reassessing the credit quality of their exposures under Basel I. Indeed, under Basel I, risk-weighted exposure amounts depended on the maturity of the exposure and the type of the obligor-factors which do not normally change during the life of the exposure.

Under the new regime, banks must devote significant internal resources to measurement and management of their credit risks throughout the life of their exposures.

3. Calculation of Capital Requirements

Capital requirements represent banks' UL. Risk weights, and thus capital requirements, are calculated using banks' estimates of risk parameters in accordance with complex formulas prescribed by the IRB. These formulas are based on modern risk management techniques that involve quantitative assessment of risk. The mechanics of calculating capital requirements varies depending on the type of exposure.

4. Classification of Exposure

The IRB recognizes that there can be significant differences across key risk factors, ratings criteria and historical loss characteristics associated with different business lines or portfolios. For example, political risk factors are very important for assessment of sovereign exposures, but are not relevant for retail exposures. Banks have historically recognized – for the purposes of internal assessment of economic capital – the differences in the distribution of credit loss events for different types of portfolios and the correlation between specific risk characteristics and levels of unexpected loss or required capital.

On that basis, the IRB differentiates, broadly, between seven classes of exposures: (1) corporates, (2) sovereigns, (3) banks, (4) retail, (5) equity, (6) securitization, and (7) noncredit-obligation assets.

IRB banks are required to assign each of their banking-book exposures to one of those classes. If an exposure does not fall within the definition of any class, it will be categorized as a corporate exposure for the purposes of the IRB.

i. Corporate, Bank and Sovereign Exposures
Capital requirements for corporate, bank and sovereign exposures are calculated by applying quantitative inputs of PD, LGD, EAD and M for each specific exposure to an IRB prescribed formula. The IRB regime offers a modified formula for exposures to small- and medium sized enterprises that have annual sales of less than EUR 50 million.

ii. Retail Exposures
For retail exposures, the IRB offers only an advanced evaluation methodology. Accordingly, the key parameters of PD, LGD and EAD are internally estimated by the bank. The IRB distinguishes between three broad sub-categories of retail exposures, each of which provides a separate risk weight formula.

iii. Specialized Lending
Unlike other forms of corporate lending, there are several sub-categories of wholesale specialized lending, which encompass the financing of individual projects where the repayment is highly dependent on the performance of the underlying pool or collateral.

For all sub-categories of specialized lending, except for high volatility commercial real estate, a bank may use the IRB general framework for corporate exposures. Where it is not possible to provide internal estimates in accordance with the IRB requirements, a bank may classify a specialized lending exposure as one of five distinct quality grades, each of which carries a specific risk weight. High volatility commercial real estate is generally risky and therefore subject to separate treatment, which is more conservative than the IRB general corporate framework.

iv. Equity
The IRB offers three different approaches to calculating capital requirements for equity exposures. The simple risk weight approach prescribes the following risk weights depending on the composition of the equity portfolio:

- 190% for private equity exposures in sufficiently diversified portfolios;
- 290% for exchange traded equity exposures; and
- 370% for all other equity exposures.

Capital requirements are then calculated as a function of the applicable risk weight and the exposure value calculated in accordance with the IRB rules.

The second approach is based on the PD/LGD approach for corporate exposures but subject to certain limitations. The third approach is based on banks' internal value-at-risk models. Overall, the treatment of equity exposures under the IRB is significantly less favorable than that used under the standardised approach.

5. Credit Risk Mitigation
The IRB recognizes the benefits of eligible credit risk mitigation (CRM) when calculating capital requirements for corporate, sovereign, bank and equity exposures. IRB banks may recognize unfunded CRM (in the form of credit derivatives or guarantees) that meet the minimum eligibility requirements generally prescribed for unfunded CRM, as well as those additional requirements prescribed for IRB banks including the requirement that the protection provider has sufficient expertise in providing unfunded CRM.

The CRM effect of unfunded credit protection recognized by the IRB is, broadly, substitution of the PD of the obligor with that of the protection provider, subject to prescribed adjustments. AIRB banks may factor in the CRM effect of guarantees or credit derivatives by adjusting their PD and/or LGD.

Collateral is also recognised under both the FIRB and AIRB, but the effect of recognition of collateral depends upon IRB methodology used. Under the FIRB, eligible financial collateral reduces the counterparty exposure. The value of the collateral is subject to haircuts (reflecting market and exchange rate volatility) and may have to be adjusted over time.

This produces an adjusted exposure that is then used in the calculation of LGD in relation to that exposure. The range of eligible collateral is wide and includes receivables, real estate and other eligible IRB collateral. Where such other collateral is taken, an asset-class-specific LGD is assigned, depending on the degree of collateralization of the relevant exposure.

6. IRB Requirements

Banks may only apply the IRB if they receive express permission from their regulators. Such permission may only be granted if a bank's rating and risk management systems are sound and have been implemented with integrity. In practice, this means that an IRB bank must have an economic model that is appropriate for its activities, effective for risk management purposes, and which can be validated by back-testing against live data. IRB banks are subject to stringent operational requirements, some of which are mentioned below.

i. The IRB Use Test

The essential role of internal ratings in the calculation of capital requirements means that systems that a bank applies to generate internal ratings and risk parameters must be consistent with their internal use by the bank. Where there is a justifiable gap between a bank's IRB estimates and estimates used for internal purposes, the bank must demonstrate the reasonableness of that gap to its regulator. This is known as the "use" test.

ii. Stress Testing

Banks' grading must take into account adverse economic conditions as well as the risk of the occurrence of unexpected events. This creates a cyclical effect whereby capital requirements for IRB banks may increase sharply as the credit quality of their exposures deteriorates, leading to a much greater variation in capital requirements due to high sensitivity to fluctuations in the economic cycle. To mitigate the impact of cyclicality, IRB banks are required to stress test their capital requirements in order to ensure that they have an adequate capital buffer for a "rainy day".

Specific scenarios against which banks' models should be stress tested vary from one regulator to another. The UK Financial Services Authority, for example, expects banks to stress test their capital requirements against an economic downturn of such intensity as may be experienced once in 25 years.

7. Conclusion

The IRB is very credit risk sensitive, which gives hope that the reform of Basel I will be successful. There may still be substantial differences between the capital requirement of an IRB bank and its internal assessment of its own risk position, but regulators will expect to see the gap between the two closing as evidence that a bank's capital requirements adequately reflect its credit risks.

From IRB banks' perspective, the IRB is expected to produce a lower overall capital requirement than the standardised approach. On the other hand, IRB banks will be subject to a very stringent set of minimum standards to ensure the comprehensiveness and integrity of their internal credit risk assessment capabilities. Compliance with the new regime will plainly require additional internal resources.

The IRB is undoubtedly progressive. In particular, it is consistent with the modern credit risk measurement and management practices of some sophisticated banks. However, it is portfolio invariant. It stops short of permitting banks to calculate their capital requirements on the basis of their own, or externally provided, portfolio credit risk models. Even the AIRB does not allow banks to adjust their capital requirements to factor in risk correlations between different obligors. Nevertheless, the Basel Committee has expressed its view that the IRB could ultimately pave the way for a transition towards full portfolio credit risk modeling in the future.

A further open question is how IRB banks will cope with cyclicality when capital requirements may increase sharply during economic downturn conditions but raising additional capital to satisfy the increased requirement may not be possible. Another area of the IRB that may cause concern is the lack of adequate treatment of liquidity risks; recent market events in the US and Europe have shown how vulnerable markets are to liquidity issues. As the industry grapples with Basel II, clearly some are already anticipating further reform.

I. Money Laundering

Money laundering is disguising illegal sources of money so that it looks like it came from legal sources. Money laundering often occurs in three steps. Some of these steps may be omitted, depending on the circumstances; for example, non-cash proceeds that are already in the financial system would have no need for placement

1. Placement
Cash is introduced into the financial system by some means.

2. Layering
Complex financial transaction is carried out in order to camouflage the illegal source.

3. Integration
Acquisition of wealth generated from the transactions of the illicit funds.

II. Methods of Money Laundering

Money laundering takes several different forms although most methods can be categorized into one of a few types. These include bank methods, smurfing also known as structuring, currency exchanges, and double-invoicing.

1. Structuring or Smurfing
It is a method of placement by which cash is broken into smaller deposits of money, used to defeat suspicion of money laundering and to avoid anti-money laundering reporting requirements. A sub-component of this is to use smaller amounts of cash to purchase bearer instruments, such as money orders, and then ultimately deposit those, again in small amounts.

2. Bulk Cash Smuggling
Physically smuggling cash to another jurisdiction, where it will be deposited in a financial institution, such as an offshore bank, with greater bank secrecy or less rigorous money laundering enforcement.

3. Cash-intensive Businesses
A business typically involved in receiving cash will use its accounts to deposit both legitimate and criminally derived cash, claiming all of it as legitimate earnings. Often, the business will have no legitimate activity.

4. Trade-based Laundering
Under- or over-valuing invoices in order to disguise the movement of money.

5. Shell Companies and Trusts
Trusts and shell companies disguise the true owner of money. Trusts and corporate vehicles, depending on the jurisdiction, need not disclose their true, beneficial, owner.

6. Bank Capture
Money launderers or criminals buy a controlling interest in a bank, preferably in a jurisdiction with weak money laundering controls, and then move money through the bank without scrutiny.

7. Casinos

An individual will walk in to a casino or a horse race track with cash and buy chips, play for a while and then cash in his chips, for which he will be issued a cheque. The money launderer will then be able to deposit the cheque into his bank account, and claim it as gambling winnings. If the casino is controlled by organized crime and the money launderer works for them, the launderer will lose the illegally obtained money on purpose in the casino and be paid with other funds by the criminal organization.

8. Real Estate

Real estate may be purchased with illegal proceeds, and then sold. The proceeds from the sale appear to outsiders to be legitimate income. Alternatively, the price of the property is manipulated; the seller will agree to a contract that under-represents the value of the property, and will receive criminal proceeds to make up the difference.

9. Black Salaries

Companies might have unregistered employees without a written contract who are given cash salaries. Black cash might be used to pay them.

III. Anti-Money Laundering

Anti-money laundering (AML) is a term mainly used in the financial and legal industries to describe the legal controls that require financial institutions and other regulated entities to prevent detect and report money laundering activities.

Anti-money laundering guidelines came into prominence globally as a result of the formation of the *Financial Action Task Force* (FATF) and the promulgation of an international framework of anti-money laundering standards

An effective AML program requires a jurisdiction to have criminalized money laundering, given the relevant regulators and police the powers and tools to investigate; be able to share information with other countries as appropriate; and require financial institutions to identify their customers, establish risk-based controls, keep records, and report suspicious activities.

IV. Anti-Money Laundering in Canada

Financial Transaction and Reports Analysis Centre of Canada (FINTRAC) is responsible for investigation of money laundering and terrorist financing cases that are originating or destined for Canada. The financial intelligence unit was created by the amendment of the Proceeds of Crime (Money Laundering) Act in December 2001 (via Bill C-25) and created the Proceeds of Crime (Money Laundering) and Terrorist Financing Act.

Financial institutions in Canada are required to track large cash transactions (daily total greater than CAD$10,000.00 or equivalent value in other currencies) that can be used to finance terrorist activities in and beyond Canada's borders and report them to FINTRAC.