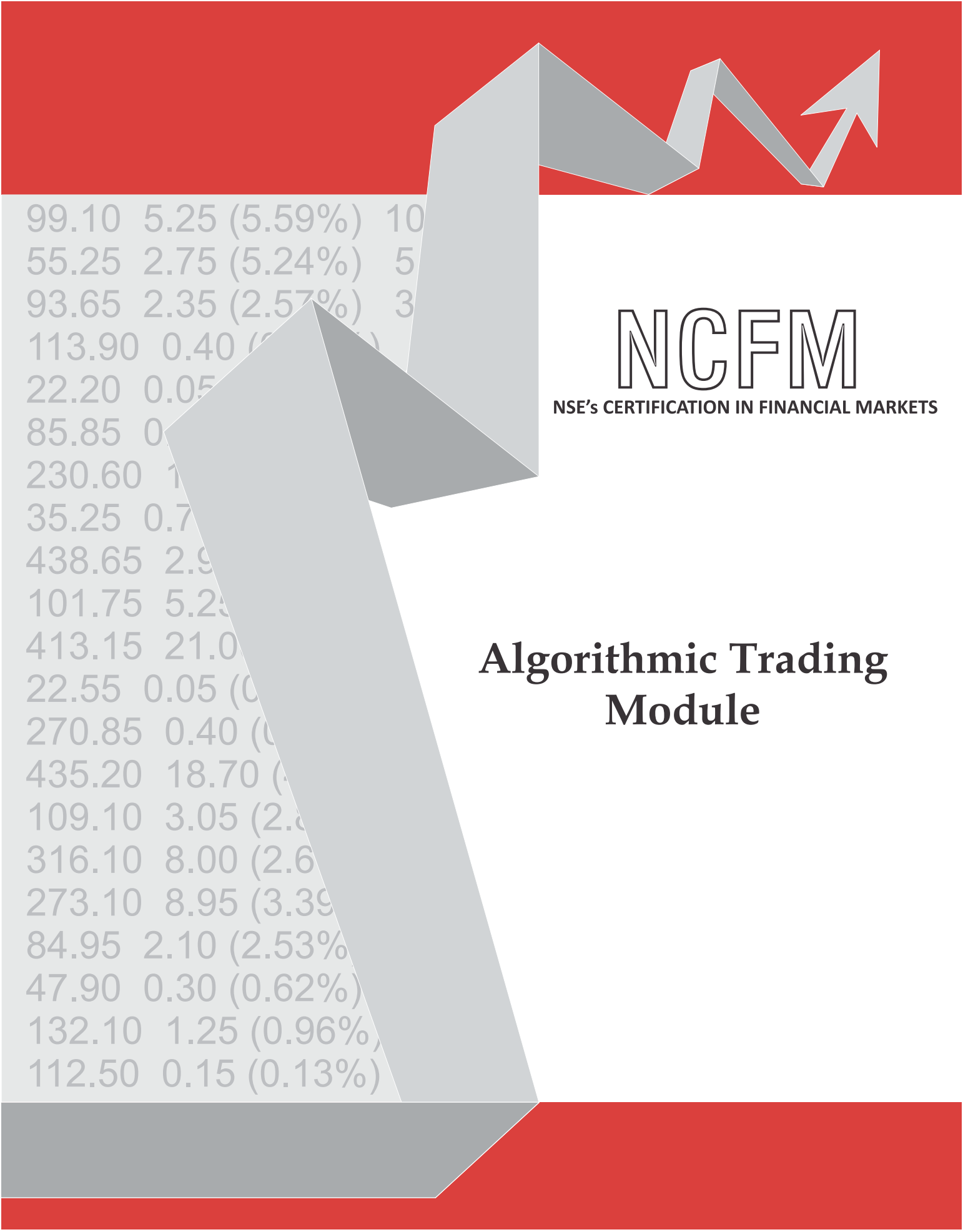


NCFM

NSE's CERTIFICATION IN FINANCIAL MARKETS

Algorithmic Trading Module

NATIONAL STOCK EXCHANGE OF INDIA LIMITED

NCFM

NSE's CERTIFICATION IN FINANCIAL MARKETS

ALGORITHMIC TRADING MODULE

NATIONAL STOCK EXCHANGE OF INDIA LIMITED

Test Details

Sr. No.	Name of Module	Fees (Rs.)	Test Duration (in minutes)	No. of Questions	Maximum Marks	Pass Marks (%)	Certificate Validity (in yrs)	Negative Marking
	FOUNDATION							
1	Algorithmic Trading Module	6840 *	120	100	100	60	3	YES
2	Financial Markets: A Beginners' Module ^	1710 *	120	60	100	50	5	NO
3	Mutual Funds : A Beginners' Module	1710 *	120	60	100	50	5	NO
4	Currency Derivatives: A Beginner's Module	1710 *	120	60	100	50	5	NO
5	Equity Derivatives: A Beginner's Module	1710 *	120	60	100	50	5	NO
6	Interest Rate Derivatives: A Beginner's Module	1710 *	120	60	100	50	5	NO
7	Commercial Banking in India: A Beginner's Module	1710 *	120	60	100	50	5	NO
8	FIMMDA-NSE Debt Market (Basic) Module	1710 *	120	60	100	60	5	YES
9	Securities Market (Basic) Module	1710 *	120	60	100	60	5	YES
10	Clearing Settlement and Risk Management Module	1710*	60	75	100	60	3	NO
	INTERMEDIATE							
1	Capital Market (Dealers) Module ^	1710 *	105	60	100	50	5	YES
2	Derivatives Market (Dealers) Module ^ [Please refer to footnote no. (i)]	1710 *	120	60	100	60	3	YES
3	Investment Analysis and Portfolio Management Module	1710 *	120	60	100	60	5	YES
4	Fundamental Analysis Module	1710 *	120	60	100	60	5	YES
5	Options Trading Strategies Module	1710 *	120	60	100	60	5	YES
6	Operations Risk Management Module	1710 *	120	75	100	60	5	YES
7	Banking Sector Module	1710 *	120	60	100	60	5	YES
8	Treasury Management Module	1710 *	120	60	100	60	5	YES
9	Insurance Module	1710 *	120	60	100	60	5	YES
10	Macroeconomics for Financial Markets Module	1710 *	120	60	100	60	5	YES
11	NSDL–Depository Operations Module	1710 *	75	60	100	60 #	5	YES
12	Commodities Market Module	2052 *	120	60	100	50	3	YES
13	Surveillance in Stock Exchanges Module	1710 *	120	50	100	60	5	YES
14	Corporate Governance Module	1710 *	90	100	100	60	5	YES
15	Compliance Officers (Brokers) Module	1710 *	120	60	100	60	5	YES
16	Compliance Officers (Corporates) Module	1710 *	120	60	100	60	5	YES
17	Information Security Auditors Module (Part-1)	2565 *	120	90	100	60	2	YES
	Information Security Auditors Module (Part-2)	2565 *	120	90	100	60		YES
18	Technical Analysis Module	1710 *	120	60	100	60	5	YES
19	Mergers and Acquisitions Module	1710 *	120	60	100	60	5	YES
20	Back Office Operations Module	1710 *	120	60	100	60	5	YES
21	Wealth Management Module	1710 *	120	60	100	60	5	YES
22	Project Finance Module	1710 *	120	60	100	60	5	YES
23	Venture Capital and Private Equity Module	1710 *	120	70	100	60	5	YES
24	Financial Services Foundation Module ###	1140 *	120	45	100	50	NA	NO
25	NSE Certified Quality Analyst $	1710 *	120	60	100	50	NA	YES
	ADVANCED							
1	Financial Markets (Advanced) Module	1710 *	120	60	100	60	5	YES
2	Securities Markets (Advanced) Module	1710 *	120	60	100	60	5	YES
3	Derivatives (Advanced) Module [Please refer to footnote no. (i)]	1710 *	120	55	100	60	5	YES YES
4	Mutual Funds (Advanced) Module	1710 *	120	60	100	60	5	YES
5	Options Trading (Advanced) Module	1710 *	120	35	100	60	5	YES
6	FPSB India Exam 1 to 4**	2500 per exam *	120	75	140	60	NA	N/A
7	Examination 5/Advanced Financial Planning **	6000 *	240	30	100	50	NA	N/A
8	Equity Research Module ##	1710 *	120	49	60	60	2	YES
9	Issue Management Module ##	1710 *	120	55	70	60	2	YES
10	Market Risk Module ##	1710 *	120	40	65	60	2	YES
11	Financial Modeling Module ###	1140 *	120	30	100	50	NA	NO
12	Certified Credit Research Analyst (CCRA) – Level 1	1710*	120	80	120	60	NA	NO
13	Certified Credit Research Analyst (CCRA) – Level 2	2565*	180	85	120	60	NA	NO
1	NSE's Capital Market Aptitude Test (NCMAT)	1710*	120	100	100	60	NA	NO

* **in the 'Fees' column - indicates module fees inclusive of service tax**
^ Candidates have the option to take the tests in English, Gujarati or Hindi languages.
\# Candidates securing 80% or more marks in NSDL-Depository Operations Module ONLY will be certified as 'Trainers'.
** Following are the modules of Financial Planning Standards Board India (Certified Financial Planner Certification)
- FPSB India Exam 1 to 4 i.e. (i) Risk Analysis & Insurance Planning (ii) Retirement Planning & Employee Benefits (iii) Investment Planning and (iv) Tax Planning & Estate Planning
- Examination 5/Advanced Financial Planning
Modules of Finitiatives Learning India Pvt. Ltd. (FLIP)
Module of IMS Proschool
$ Module of SSA Business Solutions (P) Ltd.
~ Module of Association of International Wealth Management of India

The curriculum for each of the modules (except Modules of Financial Planning Standards Board India, Finitiatives Learning India Pvt. Ltd. and IMS Proschool) is available on our website: www.nseindia.com > Education > Certifications.

Note: (i) SEBI vide notification no. LAD-NRO/GN/2012-13/30/5474 dated January 11, 2013 has specified the NISM-Series-VIII-Equity Derivatives Certification Examination as the requisite standard for associated persons functioning as approved users and sales personnel of the trading member of an equity derivatives exchange or equity derivative segment of a recognized stock exchange.

Contents

Distribution of weights of the Algorithmic Trading Module Curriculum

Chapter No.	Title	Weights (%)
1	Introduction to Algorithmic Trading	12
2	Order Types	15
3	Trading Strategies	19
4	System Architecture	19
5	Risk Management in Algorithmic Trading	19
6	Audit and Compliance Processes	16

Note: Candidates are advised to refer to NSE's website: www.nseindia.com, click on 'Education' link and then go to 'Updates & Announcements' link, regarding revisions / updations in NCFM modules or launch of new modules, if any.

The content has been developed by QuantInsti, which is a pioneering institute for Algorithmic & Quantitative Trading education in Asia.

Chapter 1 Introduction to Algorithmic Trading

With the advent of the modern computer world exchange based trading has undergone a sea change. Since historical times, people have used advantage of faster information to derive profits in trading – be it Rothschild who posted his men at war-sitesso that he could be the first to learn the outcome of the England-France war and derive abnormal profits or Reuters who used the pigeons to provide information to his clients faster that were much faster than the post train, giving faster access to stock news from the Paris stock exchange. Information today travels at a rate faster than any other time in recorded human history, and therefore those who utilize this faster pace of transfer of information could benefit in their trading operations.

As a natural response to this increased flow of information, computers have come to play a large part in the trading on exchanges - beginning with back office to streamline operations, to finally sending an order to the exchange based on predefined rules. The usage of computers for sending an order to the exchange based on predefined rules is broadly called algorithmic trading.

1.1 Evolution of Algorithmic Trading

The evolution of algorithmic trading can be traced back to both independent sell side and the buy side endeavours in trying to leverage the falling prices of computational power to create scalable infrastructural advantages.

As exchanges moved in the direction of electronic trading across the world, with NASDAQ establishing the electronic board in 1971 and other exchanges following suit, computers came to play a large part in the market place. This reduced the time required to process the post trade information and also found way in lives of analysts trying to forecast the markets.

Fischer Black (popularly known for the Black-Scholes option pricing model) asked in 1971 whether trading could be automated and if the market maker (specialist) could be replaced by a set of instructions using a computer. Within three decades, market forces had given a response to the question and the answer was “Yes”.

Early to this changing scenario were the buy side and proprietary trading participants who approached the trading systems and algorithms from the perspective of opportunistic advantage and developed strategies that could identify profit opportunities and execute profitable trades before manual traders could react. These activities were demonized when the markets fell drastically on one single trading session in 1987 (more than 20% drop in prices in a day, and much of the blame was heaped on program trading which were execution instructions to shift the portfolio from stocks to bonds and led to a cascading effect in the markets).

On the sell side the firms realized that they could create frameworks and offer it to their buy side clients to facilitate their trading strategies. The first generation of the sell side strategies were simple order slicing which primarily split large order sizes to small individual orders and managed the order flow. The later generations evolved into complex systems that seek to minimize not only the total cost of transaction but also optimize the liquidity constraints.

The growth of algorithmic trading is very closely linked to the development of the electronic trading market. The important milestones in the global electronic trading industry are tabulated below

Year	Event
1969	Instinet allowed electronic block trading
1971	NASDAQ electronic board started
1972	Cantor establishes first electronic market place for US Government securities
1976	NYSE DOT routes small orders.
1978	ITS links NYSE and other US Stock Exchanges
1980	Instinet enables DMA to US exchanges
1982	Tokyo Stock Exchange introduces Computer assisted Order Routing and Execution System
1986	Paris Bourse introduced an electronic trading system
1988	MTS platform creates secondary market for Italian government bonds.
1992	CME launches first version of GLOBEX electronic futures platform
1993	EBS adds competition for spot FX
1997	SEC changes order handling rules
1998	Eurex launches first fully electronic exchange for futures
2001	Liquidnet ATS created allowing "dark pool" buy side crossing for equities.
2007	US regulation NMS, European MiFID (Markets in Financial Instruments Directive) regulation come into force

1.2 What is Algorithmic Trading

An algorithm is a set of instructions for accomplishing a task. Trading using algorithms has been in the markets for a long time and has been known simply as rule based trading. Trading using algorithms did not require the computer to send out the eventual order to the exchange – this is the key step which differentiates rule based trading from algorithmic trading.

Algorithmic trading as defined by Indian Regulator SEBI, vide circular no. MRD/DP/09/2012 dated March 30, 2012 defines algorithmic trading as *–Any order that is generated using automated execution logic shall be known as algorithmic trading.*

In the United States, CFTC [Commodity Futures Trading Commission] technical advisory group on Automated and High Frequency Trading defines algorithmic trading as [*use of*] *algorithms for decision making, order initiation, generation, routing, or execution, for each individual transaction without human direction; Orders sent to an electronic marketplace must be generated by computer based decision making "the algorithm" as opposed to being sent by a human (e.g. "point and click").*

For facilitating the human-machine interaction of any particular algorithmic trading strategy there could be a set of values that are filled in by the trader, these values are called parameters and are used by the algorithm to evaluate the mathematical expression which results in estimation of order details - the price, size and side of the order.

1.3 Different Trading Methodologies

Following is the classification of different kind of algorithmic trading strategies based on the typical holding period:

Strategy Description	**Typical Holding Period**
Automated liquidity provision Quantitative algorithms for optimal pricing and execution of market-making positions	<1 minute
Arbitrage Strategies Index Arbitrage Put-Call-Parity	No specific time period but generally <1 minute during volatile markets
Machine Readable News Based	<1 minute
Market microstructure trading Identifying trading party order flow through reverse engineering of observed quotes	<10 minutes
Event trading Short-term trading on macro events	<1 hour
Deviations arbitrage Statistical arbitrage of deviations from equilibrium: triangle trades, basis trades, and the like	<1 day
Execution Strategies Volume Weighted Average Price Time Weighted Average Price Percentage Of Volume	Order Size dependent
Portfolio Trading	No specific time period
Smart Order Routing	No specific time period

1.4 Trends in Algorithmic Trading: Global and India

Algorithmic Trading Trends in Developed Markets

American markets and European markets generally have a higher proportion of algorithmic trades than other markets, and estimates since 2008 have ranged as high as 73% proportion in some markets.

Various studies indicate more than 50% of the US equity trading volume was through algorithmic trading with High Frequency firms being the highest contributor to the volumes.

Equity Derivative markets are fairly easy to integrate into algorithmic trading along with option trading and multiple legs can be executed simultaneously.

In the Foreign exchange markets

In the foreign exchange markets, use of algorithmic trading strategies increased to 16% in 2011 from 12% in 2010 among the market's biggest and most active traders - those generating more than $50 billion in annual FX trading volume.

Algorithmic TradingTrends in India

India has gone through a recent but swift algorithmic trading revolution since the regulator SEBI permitted Direct Market Access (DMA), i.e. a facility that allows brokers to offer clients direct access to the exchange trading system through the broker's infrastructure without manual intervention by the broker, in 2008. Order messages have surged from 30 million per day five years ago to more than 300 million on the National Stock Exchange of India (NSE) alone in 2012. Algorithmic trading based volume contributes a significant percentage to the overall exchange volumes.

Milestones in India

Year	Event
Apr, 2008	SEBI allows Direct Market Access (DMA).
Aug, 2010	Smart Order Routing Introduced.
Mar, 2012	SEBI issues broad guidelines for algorithmic trading
Jan, 2013	Forward Market Commission (FMC) issues guidelines for algorithmic trading in commodities.

1.5 Benefits of Algorithmic Trading

The rapid growth of trading activities involving algorithms has led to the debate on the advantages and disadvantages of algorithmic trading in the print media as well as academic literature. Algorithmic trading has led to an improvement of the basic quality of the market, and potentially decreased volatility over short time-frames along with increased liquidity. The advantages can be classified broadly from the perspective of a retail investor and also from the perspective of the market participant who is trading using the algorithms.

Stability

Algorithmic trading brings stability across various asset classes. Unlike manual trading, which is limited in approaching activities in a sequential manner; algorithms can process information

in parallel and take actions. Due to this any price sensitive information is immediately reflected in all the asset classes simultaneously and therefore a relatively more stable market is created.

Liquidity

Algorithms can react quickly to any new information flow and therefore they can update their quotes much faster than humans; this leads to a narrower bid/ask spread because the possibility of trades happening on stale information reduces and consequently losses due to adverse selection are lower. This significantly reduces the impact cost for the market participants.

Increased Market Efficiency

As new information gets reflected in the price almost immediately it increases the efficiency of the market and aids price discovery in a more orderly method. This leads to a more efficient market and therefore an increase in welfare of all market participants.

Uptime

These systems are able to operate all across the market hours and decisions can be made immediately and don’t suffer from fatigue.

Risk Management

Risk management is automated using computers and it helps in eliminating the possible operational human error

Speed

Lead to a faster decision making process devoid of emotions

Other advantages include reduction in cost per trade and consistent trade trail meets financial control and regulatory requirements.

Self assessment test:

- For algorithmic trading, firms aiming for higher profits have invested a lot in having faster access to:
  - Insider information
  - **Information**
  - Coolants
  - None of the above

- The first trading destination that allowed electronic block trading is:
  - NASDAQ
  - NYSE
  - **Instinet**
  - LSE

- Which of the following is least likely to be an algorithmic trading order?
  - VWAP order
  - TWAP order
  - **Point and Click order**
  - All of the above

- On NSE, Algorithmic Trading is only allowed for Equity Futures and Options.
  a. True
  b. False

- Dark pools for trading equities are available for Indian stocks
  a. True
  b. False

Chapter 2 Order Types

Orders are instructions sent to exchange by participants regarding their trading intentions. Orders allow market participants to communicate their requirements, in terms of Time, Price and Conditionality. The understanding of basic order types and their impacts on order book is important in order to develop and optimize algorithmic trading strategies.

Exchanges support various order types in order to cater to needs of traders and investors. The order types can be broadly divided into the following categories –

- Time Conditions
- Price Conditions
- Other (including conditionality) Conditions

2.1 Time Conditions

- GTC - A Good Till Cancelled (GTC) order is an order that remains in the system until it is cancelled by the Trading Member. It will therefore be able to span trading days if it does not get matched. The maximum number of days a GTC order can remain in the system is notified by the Exchange from time to time.
- GTD - A Good Till Days/Date (GTD) order allows the Trading Member to specify the days/date up to which the order should stay in the system. At the end of this period the order will get flushed from the system. Each day/date counted is a calendar day and inclusive of holidays. The days/date counted is inclusive of the day/date on which the order is placed. The maximum number of days a GTD order can remain in the system is notified by the Exchange from time to time.
- Day Order: A day order is valid for the day on which it is entered. If the order is not executed during the day, the system cancels the order automatically at the end of the Day.
- Immediate or Cancel (IOC) Order: An IOC order allows the user to buy or sell as soon as the order is released into the system, as long as the price conditions are matched. If the price conditions are not matched, the order is cancelled from the system. In case a partial match is possible for the order, the remaining unmatched order is cancelled immediately.

2.2 Price Conditions

- **Market Price:** Market orders have no price specified at the time order is released into the system. For a Buy Market Order, the system matches the Sell Limit Orders in the Order Book and for the Sell Market Order; system matches the Buy Limit Orders.

- **Limit Price:** An order to buy a specified quantity of a security at or below a specified price, or an order to sell it at or above the specified price. This ensures that the participant never pays a worse price than the limit price set.
- **Stop loss:** This order type allows the participant to release an order into the system after the market price of the security reaches or crosses a threshold price.

2.3 Other Conditions

Disclosed Quantity (DQ) is an order with a disclosed quantity allows the market participant to disclose only a percentage of the overall single order quantity on the exchange. For example, an order of 1000 with a disclosed quantity condition of 20% will mean that 200 are displayed to the market at a time.

Price-Time Priority

The principle of price/time priority refers to both orders and quotes. When an order is entered into the order book, it is assigned a timestamp. This timestamp is used to prioritize orders in the order book with the same price - the order entered earliest at a given price limit gets executed first.

When a new order (or quote) is entered, Exchange first checks the limits of all orders contained in the central order book. If the incoming order is immediately executable, meaning it is capable of being matched against an existing order or orders; one or more transactions are generated.

To be immediately executable, the order must be either of the following:

- A market order, where opposite limit orders already exist in the order book
- An order to buy at a price at or above the lowest ask in the order book
- An order to sell at a price at or below the highest bid in the order book.

Orders may not necessarily be executed at a single price, but may generate several partial transactions at different prices. When a large order executes against the total available quantity at a given price level, the next best price level becomes best. This process continues as long as the incoming order remains executable. If not executed upon entry, an order is held as a limit order in the central order book.

Also, it is possible for a single order to generate multiple executions at different points in time. For example, an order may generate a partial execution upon entry, while the remaining open order remains in the order book. The open portion may get executed a minute later, an hour later, till the end of the current trading day or may not get executed at all.

Market orders have the highest priority for matching. Since the purpose of the market order is to be executed as quickly as possible at the best possible price, they are entered without execution restrictions. If several market orders are booked in the order book, Exchange takes into account the timestamp of the orders to establish matching priority. The earliest market order received by the exchange receives the highest priority.

In the case of limit orders, orders with the best possible prices (highest price limit for buy orders, lowest price limit for sell orders) always take precedence in the matching process over other orders with worse prices. Again, if the limit orders have the same price limit, the criterion used for establishing matching priority is the order timestamp. This is the concept of Price Time Priority.

2.4 Market Orders

Market Order is an order type that trades the given quantity at the best possible price at that specific instant in the order book. The main risk of the market order is in the uncertainty of the execution price, and on the other hand there is high certainty of execution. These orders are not visible in the Order Book, but are executed as soon as they reach the system.

In order to understand the impact of Market Order, consider the Order Book -

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
53	82.55	83.20	512
200	82.50	83.25	45

If a Sell Market Order of size 500 hits the order book at this instant, then, it will cross with Limit Orders of Bid Price 82.75. The Sell Market order would report the price of execution as 82.75 and the order book would look as below.

Bid Size	Bid Price	Ask Price	Ask Size
100	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
53	82.55	83.20	512
200	82.50	83.25	45

If the Sell Market Order of size 700 hits the previous order book (with the bid size of 600 at 82.75), then it will cross with Limit Order of Bid Price 82.75, size 600 and then hit the lower

price limit orders, till the size is met. In this case, the Best Bid of 82.75 is completely executed and then 100 shares at Price 82.65 are also executed. The order book at this instant would look like

Bid Size	Bid Price	Ask Price	Ask Size
52	82.65	82.90	23
212	82.60	83.00	300
53	82.55	83.15	143
200	82.50	83.20	512
65	82.45	83.25	45

Thus the execution price received for this market order of size 700 is 82.7357 which is worse than the Best Bid level of 82.75. Since the liquidity at the Best Bid was exhausted, the order reached lower levels and thus the Sell Price was worse. This is termed as Slippage on account of market conditions and lack of liquidity in Order Book.

There can be scenarios when there is not sufficient liquidity in entire order book.

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
		83.20	512
		83.25	45

If at this instant a Sell market order for 1000 shares arrives, then it will take out the entire liquidity from the bid side of the order book. The remaining 36 shares will remain standing as limit orders at Last Traded Price of 82.60.

Bid Size	Bid Price	Ask Price	Ask Size
		82.60	36
		82.90	23
		83.00	300
		83.15	143
		83.20	512

Market Orders can have market impact and therefore usage of large size in market orders is not preferred. Such orders can be split into several smaller orders. The benefit of market orders is immediacy and certainty of execution but it can result in considerable slippage (worse than best available market price) at times.

2.5 Limit Orders

Limit Order is an order type that trades a given quantity at a specified price or better. These orders provide liquidity in the Order Book. Limit orders will take as much liquidity as possible within the price specified. If there is no liquidity available within the price specified, then the limit order will stand in the order book till either its executed or cancelled or end of trading day. If the limit order is partially executed, then the remaining quantity will remain in the order book.

Consider the Order Book –

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
53	82.55	83.20	512
200	82.50	83.25	45

If a Buy Limit Order of Price 82.75, size 100 is added to the Order Book then Order Book is changed to the following

Bid Size	Bid Price	Ask Price	Ask Size
700	82.75	82.9	23
152	82.65	83	300
212	82.6	83.15	143
53	82.55	83.2	512
200	82.5	83.25	45

If a Buy Limit Order of Price 82.80, size 100 is added to the Order Book, then it changes to the following

Bid Size	Bid Price	Ask Price	Ask Size
100	82.80	82.90	23
600	82.75	83.00	300
152	82.65	83.15	143
212	82.60	83.20	512
53	82.55	83.25	45

If a Buy Limit Order of Price 82.90, size 23 is added to the order book (in the initial order book with 82.75 as the best bid price), then the limit order gets executed immediately. This is known as Marketable Limit Order. The resultant order book looks as follows:

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	83.00	300
152	82.65	83.15	143
212	82.60	83.20	512
53	82.55	83.25	45
200	82.50	83.45	100

In case, the Buy Limit Order size is greater than the size of the Asks that have a lower price level than Buy Price, then the Buy Limit Order will create a new Bid will created in the Order book. For example, Buy Limit Order of Price 83.00, size 500 is added to the initialOrder Book (with 23 shares at the best bid of 82.90), the Order Book looks like the following –

Bid Size	Bid Price	Ask Price	Ask Size
177	83.00	83.15	143
600	82.75	83.20	512
152	82.65	83.25	45
212	82.60	83.45	100
53	82.55	83.50	200

The main advantage of Limit Order is that there is no uncertainty in execution price; however the risk is in uncertainty in execution. If the price moves away from Limit Order Price, then the order might not get executed.

2.6 Immediate-or-Cancel Orders

An Immediate or Cancel (IOC) order allows a participant to buy or sell a security as soon as the order is released into the market, failing which the order will be removed from the market. Partial match is possible for the order, and the unmatched portion of the order is cancelled immediately.

Consider the Order Book –

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
53	82.55	83.20	512
200	82.50	83.25	45

If a Buy IOC Order of Price 82.75, size 100 is added to the Order Book then it gets cancelled and Order Book does not change.

If a Buy IOC Order of Price 83.00, size 100 is added to the Order Book then it gets filled with 23 shares at 82.90 and 77 shares at 83.00 and Order Book changes to -

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	83.00	223
152	82.65	83.15	143
212	82.60	83.20	512
53	82.55	83.25	45
200	82.50	83.45	100

If a Buy IOC Order of Price 82.90, size 100 is added to the initial Order Book then it gets filled with 23 shares at 82.90 and 77 shares get cancelled and Order Book changes to -

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	83.00	300
152	82.65	83.15	143
212	82.60	83.20	512
53	82.55	83.25	45
200	82.50	83.45	100

Immediate or Cancel Orders provide an advantage of getting a price not worse than indicated at the time of sending the order. Moreover, it gets filled or cancelled immediately, giving the user an advantage of maintaining lower control over this order type.

2.7 Market with Price Protection

Market Price protection functionality gives an option to a Participant to limit the risk of a market order, within a pre-set percentage of the Last Traded Price (LTP). It offers the immediate execution that Market Orders offer along with protection of an inbuilt price limit. It ensures that execution is not achieved at off-market prices. With a reasonable protection limit, it ensures a balanced mix of immediacy in execution and certainty in price. All NSE market orders are implemented as market with price protection orders. The pre-set market price protection percentage is by default set to 5% of the LTP. The participants can change the pre-set market price protection percentage.

2.8 Stop Orders

An order to buy or sell a security is when its price surpasses a particular point, thus ensuring a greater probability of achieving a predetermined entry or exit price, limiting the participant's loss or locking in his or her profit. Once the price surpasses the predefined entry/exit point, the stop order converts a market order. These orders are not visible in the order book.

Stop Loss orders are stored in Stop-Loss Book till the trigger price specified in the order is reached or surpassed. When the trigger price is reached or surpassed, the order is released in the Regular lot system. The stop loss condition is met under the following circumstances:

1. Sell order - A sell order in the Stop Loss book gets triggered when the last traded price in the normal market reaches or falls below the trigger price of the order.

2. Buy order - A buy order in the Stop Loss book gets triggered when the last traded price in the normal market reaches or exceeds the trigger price of the order.

The market order generated by a Stop Loss can lead to significant slippage especially when the markets are volatile. If the order book is as follows and a Buy SL order has been placed of size 500 with Trigger as 83.00 and a Buy Market Order of size 50 hits the Order Book.

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	82.90	23
152	82.65	83.00	300
212	82.60	83.15	143
53	82.55	83.20	512
200	82.50	83.25	45

Once the Market order is processed, the Limit Order at 82.90 is traded and Limit Order at 83.00 is partially traded. However Last Traded Price matches the Trigger Price for the SL order. The Order Book at that instant, when the Buy SL Order is triggered is as follows –

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	83.00	277
152	82.65	83.15	143
212	82.60	83.20	512
53	82.55	83.25	45
200	82.50	83.45	100

At this moment, Buy SL order of size 500 is processed and it hits the order book. The Order book after execution of SL order is as follows –

Bid Size	Bid Price	Ask Price	Ask Size
600	82.75	83.20	432
152	82.65	83.25	45
212	82.60	83.45	100
53	82.55	83.50	200
200	82.50	83.75	100

2.9 Disclosed Orders

The disclosed quantity of the original order is indistinguishable from any other Limit Order in the Order Book. Every time this disclosed quantity is completely executed, a new order with price same as before and size equal to disclosed quantity is placed in the Order Book. The hidden part of the original order loses the time priority as it joins the Order Book afresh.

In the following Order Book, a Disclosed Order of original Size 1000 is placed, however only 10% of the Quantity is to be disclosed. Thus it contributes a size of 100 at Price 83.00 in the Order Book.

Bid Size	Bid Price	Ask Price	Ask Size		
600	82.75	82.90	100		
152	82.65	83.00	100	83.00	100
212	82.60	83.15	143		
53	82.55	83.20	512		
200	82.50	83.25	45		

If a Buy Market Order of size 200 hits the Order Book, It will take away the Price Levels of 82.90 and 83.00. Since the Disclosed Order is now completely executed, another order of 100 shares will be displayed and now the Order Book would be as follows –

Bid Size	Bid Price	Ask Price	Ask Size		
600	82.75	83.00	100	83.00	100
152	82.65	83.15	143		
212	82.60	83.20	512		
53	82.55	83.25	45		
200	82.50	83.45	100		

2.10 Execution Trading Strategies

Execution Trading Strategies aim to reduce market impact, improve performance versus benchmarks, and streamline the trading process. The classification of the strategies is mainly into the following categories –

- Schedule-Driven
- Opportunistic
- Evaluative

On the less "structured" side, are the opportunistic strategies, in the sense that these strategies do not have pre-defined execution schedules; instead, they utilize real-time information

to actively search for optimal times when trades can be executed. These strategies create execution schedules as they go along. At the beginning of an order, the execution schedule is not known. The schedule driven strategies basically split a large order into smaller orders and try to minimize the market impact costs while trying to reduce effect of execution on the market price.

At the other extreme, the more "structured" end – are algorithms that follow precisely defined execution schedules; are the schedule-driven strategies. All VWAP- and TWAP-based strategies, for example, can be categorized this way.

Between these two ends, lie the evaluative strategies. These strategies combine approaches of both opportunistic and schedule-driven algorithms.

Trading Benchmarks

In order to assess the performance of an execution, participants need benchmarks. These benchmarks vary according to execution methodology, asset classes and affect both investment and execution decisions. They are also reflective of intraday trading conditions. The often used benchmarks are TWAP (Time Weighted Average Price) and VWAP (Volume Weighted Average Price).

TWAP

TWAP benchmark is used in scenarios where the execution is determined by time availability. It is the average of all observed trades over a given period of time. All trades are equally weighted irrespective of their sizes. So, even small trades at extreme prices affect the TWAP in a significant way. A large order might be broken up into smaller orders and spread out evenly over a specified time period in order to lessen its market impact – that is, to avoid an adverse effect on the price of the security. A TWAP benchmark is preferred over Volume Weighted Average Price (VWAP) benchmark when the security is illiquid and where volume analysis is not of significance.

VWAP

VWAP is the most used and transparent benchmark. It gives an indication of how price has moved over a period of time, along with trade executions. VWAP is the average of all trades weighted by their volumes. In contrast to TWAP, small trade sizes at extreme prices have smaller effect on the benchmark and it is representative of the bigger trades.

2.10.1 TWAP Strategy

TWAP is the average of all observed trades over a given period of time. All trades are equally weighted irrespective of their sizes. This strategy attempts to match this benchmark by breaking down the order into equally spaced time periods.

For example, a trade of size 5000 is broken into smaller trades of 500, to be executed in 15 minutes intervals. The trading pattern is linear with time and the trade is scheduled to finish in 10 intervals. The trade execution has no relation to the market volume.

2.10.2 VWAP Strategy

The VWAP strategy aims to meet the VWAP of the given symbol. The VWAP is simply the summation of the price multiplied by the volumes at each trade divided by the summation of the volumes of each trade.

$$\text{VWAP} = \frac{\sum_n V_n * P_n}{\sum_n V_n}$$

Where,

V_n: Volume in the 'n'th trade

P_n: Price of the 'n'th trade

However, in the case of the strategy, the key is to be able to predict the volume happening on the day correctly. The most popular prediction methodology is using historical volume profiles.

2.10.3 Percentage of Volume (POV) Strategy

In POV strategy, market participant specifies the percentage of volume (of the overall exchange volume during that duration) he wants to participate in. The objective of the strategy is to slice down a big order into multiple smaller orders. The size of the smaller orders is proportional to the volume in the market as the target percentage is specified by the market participant.

The participant specifies the time duration during which he wants to participate on volume and also the target percentage. If the target percentage is high then the execution happens faster but can have a higher market impact.

Self Assessment

- A buy IOC order will not impact the order book if
  - **the order price is less than the best bid in the market**
  - the order price is equal to the best ask in the market
  - the order price is greater than the best ask in the market
  - the order price is greater than the best bid in the market

- TWAP is preferred over VWAP when
  - **the instrument is illiquid**
  - the market hours opening hours are very short
  - the order book is very condensed for that instrument
  - trading derivatives instead of stocks

- In VWAP strategy, the idea is to
  - Trade an instrument in equal volumes throughout the day
  - Trade different instruments in the ratio of their volumes traded in the market
  - **Trade an instrument in such a way so as to match the Volume Weighted price of that stock in the market for a given time period**
  - Trade an instrument every time, when beyond a particular amount of volume gets traded in the exchange

Chapter 3 Trading Strategies

Algorithmic trading openedlot of opportunities in form of various trading strategy. In the following chapter, we will be discussing various trading strategies and their application through algorithmic trading.

3.1 Calendar Spread

Definition:

A calendar spread is terminology used for trade where simultaneous Buy and Sell is being carried out on futures/options with different expiries. In a more simple term, the strategy has two legs, with one leg being Buy/Sell of a particular instrument of one expiry and the other leg being Sell/Buy of same instrument of another expiry. The idea behind the trade is to profit from the differential spread existing at different point of time over the course of expiry.

Calculation of Calendar Spread:

Suppose Stock "AAA" current month is quoting at Bid: 100 and Ask: 100.25, while far month is quoting at bid: 101.10 and Ask: 101.35. Then, the calendar spread available in the market is buying spread is: 1.35 and sell spread is 0.85.

Execution of Calendar Spread:

Algorithmic trading plays important role while execution of the calendar spread. Consider the above example and suppose, a trader wants to take the spread available in the market and can execute the spread available in the market. However, trader can also choose to quote in one leg (in either expiry) and take the price in other expiry as soon as order is hit in the expiry where trader is quoting.

Calendar Spread in options:

Calendar spread in option is more intricate. The strategy can be executed with calls or puts also. It involves (very similar to calendar spread in futures) buying one option and selling another option of the same type and strike, but with different expiration.

Options in near-month expiry typically have more time decay than far months. The strategy profits from this difference in decay rates. It is best executed when implied volatility is low and when there is implied volatility "skew" between the months used for trade.

The strategy is profitable in a limited range around the strike executed. The maximum profit is realized when the underlying expires at the strike price used.

Uses of Calendar Spread:

Calendar spread helps trader to benefit from the time decay i.e. decrease in spread over the

time of two expiries. Moreover, the calendar spread provides trader a low risk opportunity to play in the market as the strategy is protected against the extreme movement in the market since trades are taken in the both direction (BUY-SELL) on the same underlying.

Calendar Spread for the options can help trader to take advantage of time decay. Option traders often witness the time decay eating away the profits as options approach expiry. A long calendar spreads provide a low-risk way to take benefit of time decay inbuilt in different expiration dates. The strategy profits within a range. It profits from an increase in implied volatility and are therefore a low-cost way of taking advantage of low implied volatility options.

3.2 Cash Future Arbitrage Strategy

When we deal with arbitrage strategy, it refers to process of clearing the inefficiency created in related instruments in course of trading. In Cash Future Arbitrage strategy, a trader expects to profit from the difference in the prices for cash and future for the same underlying instruments. Trade is setup, usually during the early days of expiry cycle, by (typically, but not necessarily) selling the future and buying the underlying stock. Near the close of expiry, the trader would square off the position by reversing the trade i.e. buying the future and selling the shares. The extension of the strategy could be doing arbitrage between Nifty futures and the underlying constituent shares.

Definition

The trade entails selling the futures (that are quoting at a premium to the cash prices), and buys same quantity of the underlying stocks. The arbitrageurs seek to make riskless profit. The strategy becomes viable when the premium so desired to be earned is more than the opportunity (carrying) cost and transaction costs. Since such opportunities are momentarily available in the market, it becomes imperative to use algorithmic execution for the same to avoid execution related errors.

3.3 Index Arbitrage

This strategy is extension of normal Cash-Future arbitrage. The trade has two parts, with one part involving index future while other being basket of stock representing cash (stock) index value.

Definition:

Strategy designed to profit from the mispricing of the Index future and the member constituents in the index. The philosophy behind the strategy is as follows. Since both Index and the member constituents are traded instruments, there exist temporal price discrepancy due to market inefficiency in the derived index value and the actual traded index value.

Suppose Nifty Index trades at 5900 and Nifty Future trades at '5900 + X'. If cost of carry is

say 'C' and transaction cost 't'(includes brokerage cost and the liquidity cost), then

- If X > C + t implies then its profitable to setup Index arbitrage by selling Index future

Once the Index Arbitrage is setup, trader can look forward to be in trade till expiry, as Index Future price will converge to Index level.

Execution of Index Arbitrage

Accurate execution forms the backbone for this strategy. Once the arbitrage conditions are satisfied, the algorithm is supposed to execute both side of the order of arbitrage i.e. Index on one side and Equity Basket of the index constituents on other side. The execution needs to be accurate and precise. Traders can choose to send equity basket in one go or can choose to quote on the illiquid instrument first.

Once the Arbitrage is setup, the arbitrageur has an option of either square off trade before expiry (If the premium decreases and with cost of carry being covered), or rollover* future to next month. If neither of the process is followed, trader needs to offload basket of stock once the future contract expires on expiry day.

**Rollover is the process through which current position is shifted to next month. Suppose a trader is short in current month and wants to rollover. Trade would be selling the next month contract and buying the current month. Similarly, long position can be moved into next month.*

3.4 Pair Trading

Pair Trading has been one of the most popular algorithmic trading strategies across global markets. Being long and short simultaneously, the strategy provide trader to harness the relative movement between stocks without taking high unwarranted market risk.

Definition:

Pairs Trading, also known as Statistical Arbitrage Trading , is defined as trading one stock (or basket of stock) against another stock (or basket of stocks) in such a fashion that long position is taken on one Leg and Short on other. Strategy is also termed as convergence trading strategy/ "contrarian strategy"designed to harness mean-reverting behaviour of price ratio of the stocks.

Normally, strategy is executed either Rupee Neutral Basis or Market Neutral Basis. Rupee Neutral Scheme entails where the value of the both the executed Leg are similar, while in Market Neutral Basis, stocks are executed in proportion to their relative betas and it is more suitable to protect the trade from the market movement-up or down.

Compared to arbitrage strategies, the pair trading is not a risk-free strategy. Key risks involved in trading are as follows:

- Contrary to expectations, the prices of the two securities begin to diverge (drift apart), i.e. the spread picks up trend rather than mean-reverting to the original mean.
- A surprise event in a security can trigger extreme movement in pair ratio.

Strict risk management of Stop Loss is required to handle adverse situations once the mean-reverting behaviour is invalidated.

Methodology of Pair Trading:

Methodology used to determine various trading scenarios can be generated as follows. Trader calculates Pair Ratio as:

Pair ratio = Price of Stock A / Price of Stock B

The trader looks forward to Sell Pair ratio (i.e. Sell Stock A and Buy Stock B) or Buy Pair ratio (i.e. Buy Stock A and Sell Stock B) when its seems to be profitable to trade, once the spread has diverged to extreme values from the mean value.

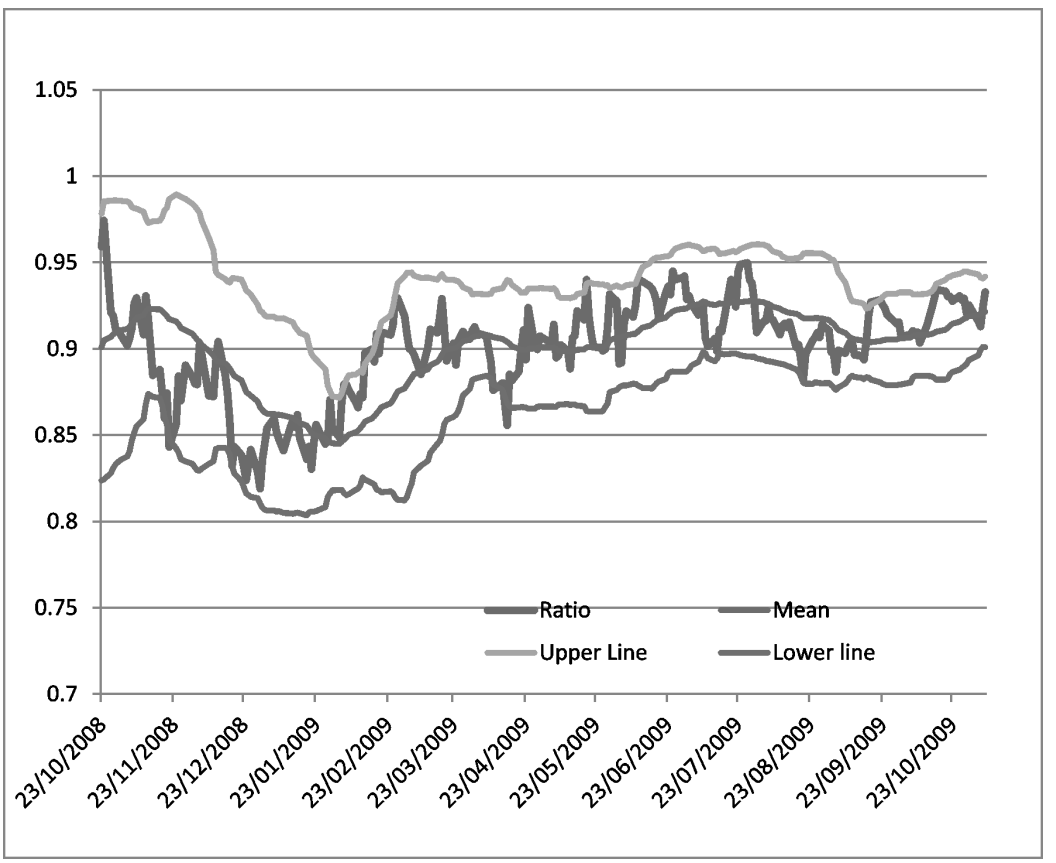


Fig 1: In the above graph, Blue line depicts Pair Ratio, Green Line Depicts typical upper bound, Purple line as typical lower Bound and Red line as average. It is to be noted that upper bound and lower bound are indicative parameters for extreme pair behaviour and no-way guarantees that the pair ratio cannot exceed beyond these values.

A typical pair trading looks as shown in graph. Trader can choose to execute Sell Pair, once the upper bound is reached / breached and Buy Pair, the lower bound is reached /breached.

3.5 News Based Trading Strategies

Traditionally, news based trading has been one of the most common form of trading followed by the traders. Traders of this genre try to gain an understanding of the market in terms of the reaction one can expect with the arrival of new information. These strategies, where the trader expects to harness the temporary mispricing occurring in the market due to sudden news, are also termed as Event Driven.

As communication becomes faster, traders utilizing such faster information could respond to events at a very quick pace. Such events could be corporate quarterly results, new merger & acquisition or economic figures released by governmental or statistical agencies.

Concept of Algorithmic News Based Trading

Various data providers provide machine readable digital news. The system is designed to make sense out of the news. A trader can input the expectation before the arrival of important financial result or policy decision by central bankers, etc and compare with actual results and take the informed decision based on it. The success in a news based trading system depends on the pre-defined trading rules chosen and the heuristic model applied in arriving at these rules.

There are significant road-blocks in such system. It becomes increasingly difficult for the system to decipher and estimate the impact of the news, if the event is highly unexpected. Moreover, system need to be adept at pricing the news and arrive at the right price since just a limit order cannot be put which will be hit. Unavailability of large enough historical data, especially in digital format makes quantifying the news a daunting task while trying to create a news based trading system. The strategies assume a specific range of parameters and keywords. However, if data lies outside the pre-defined range, it can lead to erroneous signal and thus erroneous trade. Hence, it calls for strong risk management in the event the news data being outside the known historical range.

3.6 Conversion- Reversal

Similar to cash future arbitrage, the conversion and reverse conversion helps in keeping the efficiency in the options markets. In ideal scenario, the returns from the conversion –reversal strategy should be not more than the risk free interest rate prevailing in the market. However, momentary mispricing greater than risk-free interest rate can occur. The trader looks forward to harness this mispricing occurring between the Put-Call-Future prices. When the trader executes this opportunity, the mispricing ceases to exist, leaving no room for delay

in execution. Floor Traders and the market makers have utilized this strategy profitably for a long time since they operated with lower cost of capital and transaction cost.

Definition

Conversion trading strategy involves Buying Future, Selling Call and Buying same-strike Put option (Expiry date for the options are same). Since the long created by the future buying is offset by the synthetic short created by the Selling of Call and Buying of Put, the trade creates the directional neutral trade. The difference in long future and short synthetic future is the profit trader looks forward to make.

The reverse conversion (or simply referred to as reversal) is exactly opposite to that of conversion. A future short is setup against the synthetic future long i.e., trader takes Short future, Long Call and Short Put (options being of the same-expiry and same-month) position to setup this arbitrage.

Calculation for the conversion Strategy

To have better grasp of the strategy, let us consider the following information for the stock "AAA". Assume that both cash as well as future price for AAA be quoting, bid at 99.0 & ask at 99.1; August month Call option for strike 100 trading at 3.8 (bid) and 3.9(ask); while August month Put option trading at 4.35 (bid) and 4.40(ask). A trader looking to set up the trade would be Buying future at 99.1; Selling Call option at 3.8 and Buying Put option at 4.40. To evaluate the following trade, consider the table as follows:

Option Expiry	Option Trade	Option Strike	Option Price	Intrinsic Value*	Time Value
August	Short Call	100	3.80 (bid)	0	3.8
August	Long Put	100	4.40 (ask)	0.9	3.5
Conversion Profit				Diff of Time value	0.3

**Intrinsic Value has been calculated based on the Buying Price of 99.1*

Profitability is being calculated based on the difference in the time value. So, whatever the price of the Future at expiry, the trader stands to make Rs 0.3 out of this transaction

The conversion strategy has been executed for At-the-money options, the resulting delta would for the short call option is approximately -0.5 and for the long Put option will be approximately -0.5. The net delta resulting from the combination will be nearly close to -1, which is offset by the +1 delta resulting from the long future trade. Thus, the strategy provides the trader with the direction neutrality.

Now, let us analyze at the profitability of the above trade at time of expiry

Instrument &Trade	P&L at Different Expiry Price		
	105	**100**	**95**
Short Call, 100 Strike, sold at 3.8	-1.2	3.8	3.8
Long Put, 100 strike, bought at 4.40	-4.4	-4.4	0.6
Future Buying at 99.1	5.9	0.9	-4.1
Total Profit	0.3	0.3	0.3

Fig 2

Thus, it is noted that, in the above mentioned strategy, trader stands to gain 0.3 at expiry irrespective of expiry price.

On the similar lines, we can create the reversion trade and calculate the profitability at different scenarios of expiry.

Self Assessment:

- If you want to create a rupee neutral strategy where the 2 legs involved are USDINR currency future[lot size 1000] and NIFTY future [lot size =50] for the same month. If the trade level for Nifty is 6000 and for USDINR is 60. How many lots of USD INR would you trade against 1 lot of Nifty.
  - 10
  - 3
  - 0
  - **5**

- Pair Trade can never be beta neutral
  - True
  - **False**

- A trader trades a calender spread in currency futures on NSE such that [s]he is long November [expiry on 27th November, 2013] and short December [expiry on 29th December, 2013]. At 12:15 pm (when contract expires) on 27th November, 2013.
  - Trader has zero position.
  - Trader long December short January spread.
  - **Trader has a short December position.**
  - Trade has a long January Position.

Chapter 4 Algorithmic Trading: System Architecture

Any conventional trading system would consist of the following modules in one form or another:

1) Market data adapter
   - Reads market data packets from the network.
   - Manages the market data network session if required
   - Parses the data packet and passes it on to the rest of the system if required
2) Historical data store
   - A store of all data that is being received
   - A store of all decisions taken on that data
3) Analytics module
   - This module is used for analysis over data stored in the historical data store.
   - Might involve some complex mathematics and data mining.
4) Application/Graphical Interface (GUI) for trader inputs
   - Application available to trader for operating
   - Analyze current data with visual patterns found in the data store.
   - An interface where the decisions/trading signals can be generated by the trader
   - Also provides an interface for the inputs given by trader.
5) Order Manager
   - Maintains the state of all orders.
   - Routes the orders to the destination.

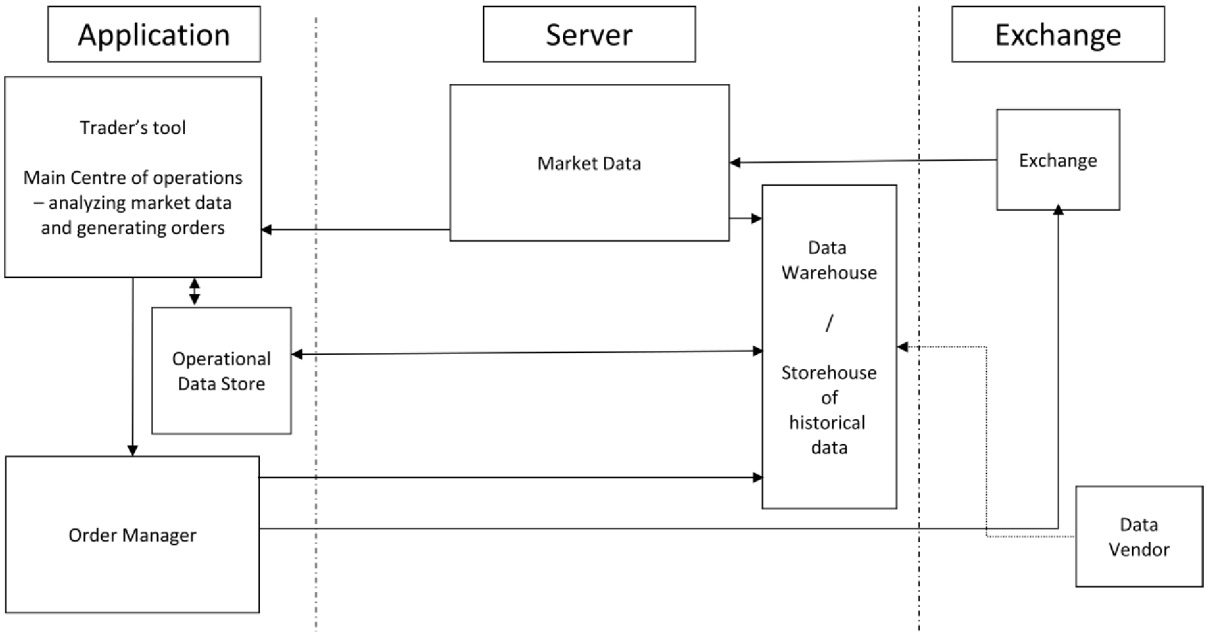


Fig1 – Structure of a conventional trading system.

With the advent of DMA and automated trading, following changes in architecture took place:

- Order management became more robust and order management logic moved from the application to the server.
- Risk management done in automated fashion in real time by the Order Management System (OMS) before the order is generated. Global position monitoring introduced as a second level of monitoring.
- Automation of analysis of historical data and decision making led to the advent of Complex Event Processing (CEP) engines. These CEP engines have their own storage requirements for event history to identify future opportunities.
- Low latency systems for generating orders and handling market data were introduced. To generate orders quickly, market events are now handled in the server instead of the application.
- With more processing power available, more complex mathematical operations are included and these are usually handled in dedicated calculation blocks (e.g., options Greek calculations).
- Risk Management checks introduced in application for checking trader inputs as well.
- Application became merely a view for the trader and a medium for inputs and monitoring positions/orders.

- Standardized protocols for communication evolved in order for the server to communicate with the exchange.
- Data normalization introduced to convert market data from the exchange format to platform specific format, since server now took on several additional tasks and the information needed to be propagated between these blocks.
- Additional regulatory storage requirements introduced requiring storage of trade information in addition to market data.
- An additional block introduced into the architecture to listen to analytics and data from third party vendors as well.
- Simulator block introduced into the architecture to test strategies. This block replays market data as well as acts as a destination for test orders.

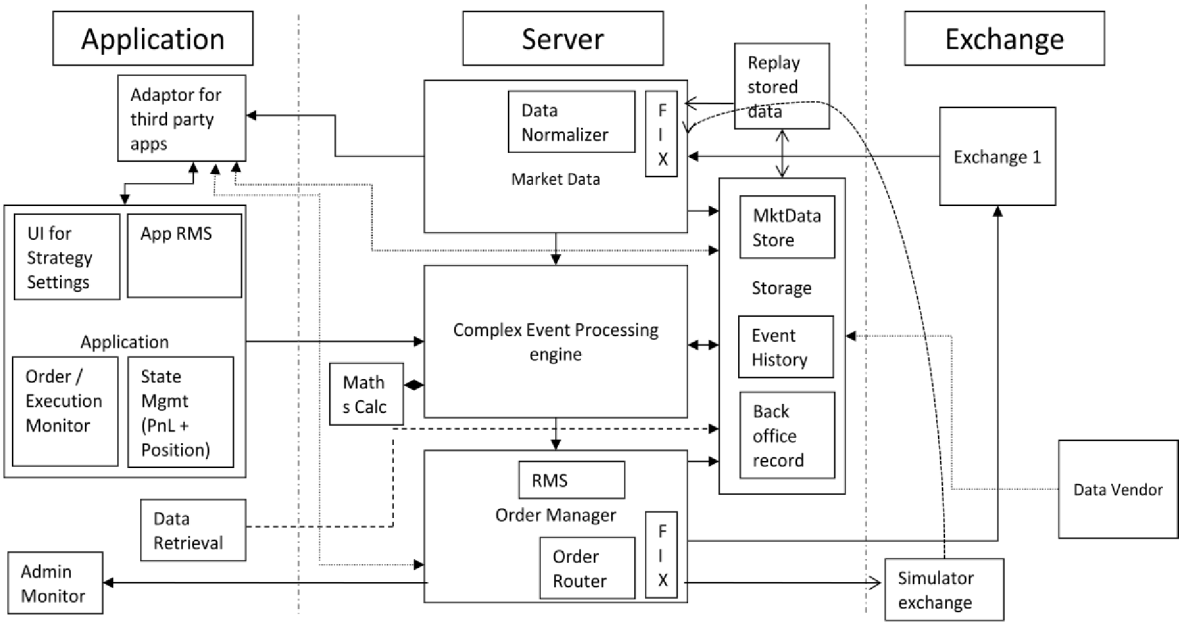


Fig 2 – Architecture of Automated Trading System

4.1 Market Data

Events in the market are communicated to the trading server over the network in the form of market data. This data forms the main input to the algorithmic trading system. Following flow illustrates how the market data flows and reaches the strategy.

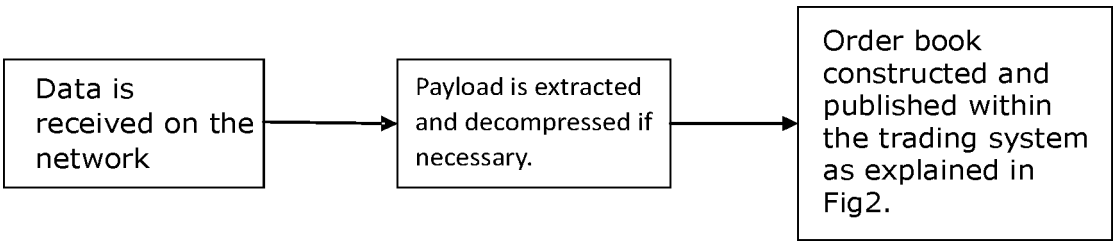


Fig 3 – Market Data processing

Market data can be received in any of the following three ways depending on the connectivity and segment.

MULTICAST SNAPSHOT DATA	Tick By tick (TBT) DATA	BUCKET TBT DATA
Is not generated on every event in the exchange. periodical snapshot	Is generated for every scrip in the segment. Much more data flowing into the trading system.	Is generated for every subscribed scrip in the session.
Multicast data, hence no sequencing guaranteed.	TCP data. Guarantees sequencing of data.	TCP data. Guarantees sequencing of data.
Order book depth is fixed by the exchange.	Order book constructed at the server end. Hence depth determined by the trading server.	Order book constructed at the server end. Hence depth determined by the trading server.
UDP server needs to be running to receive UDP data	No need of a UDP server. Trading server directly initiates TBT connection.	No need of a UDP server. Trading server directly initiates TBT connection.
Once the UDP server sends the multicast packet over the local network, every machine on that network would receive it.	The connection is between the trading server and the exchange only. No other server can listen in on this data.	The connection is between the trading server and the exchange only. No other server can listen in on this data.

MULTICAST SNAPSHOT DATA	Tick By tick (TBT) DATA	BUCKET TBT DATA
No login required	Authenticated with login and password. Login to online and offline server required. 1) login to online and offline server using username and password 2) each packet received with a sequence number for the packet 3) if sequence number is not incremental, then connect to offline server and request for missing sequence number range 4) once synchronization done, start reading from online server	Authenticated with login and password. Login to both online and offline server required. 1) login to online and offline server using username, password and list of symbols 2) each packet received with a sequence number and session sequence number for the packet 3) if session sequence number not incremental, then connect to offline server and request for missing sequence number range 4) once synchronization done, start reading from online server
Available for all segments.	Available for all segments.	Available for FO segment only.

Recently, NSE has also introduced Tick by Tick (TBT) data over multicast for connections within the NSE colocation facility. Multicast TBT is on UDP protocol and does not require the member to login to either online or offline server.

4.2 CEP Engine

The CEP engine is the core of the architecture of an algorithmic trading system. It listens to market data and determines what actions to take based on the settings and inputs given by a trader.

The input to this engine is an event. This could be

- Market data, news
- Order acknowledgement/fills/rejects
- Exchange published information
- Change of settings/inputs by the trader.

The output after the processing is

- Order request to the order manager.
- Notification to the trader and the application.

Within the CEP engine, the flow of tasks is as follows

- Decode the event and store it in the event history.
- Check if the event falls in known patterns.
- Run the decision processing rules on this event. This would determine what to do next in case a pattern is recognized.
- If an action needs to be carried out, this is communicated to the action destination outside the CEP engine.
- This action is also stored in the action-store.
- The action is also conveyed to the trader and the application.
- Remember that the processing rules themselves could be generated on the fly based on the event store and action store
- In case some complex mathematical calculations are involved, dedicated resources like CPU and memory are allocated to the CEP.

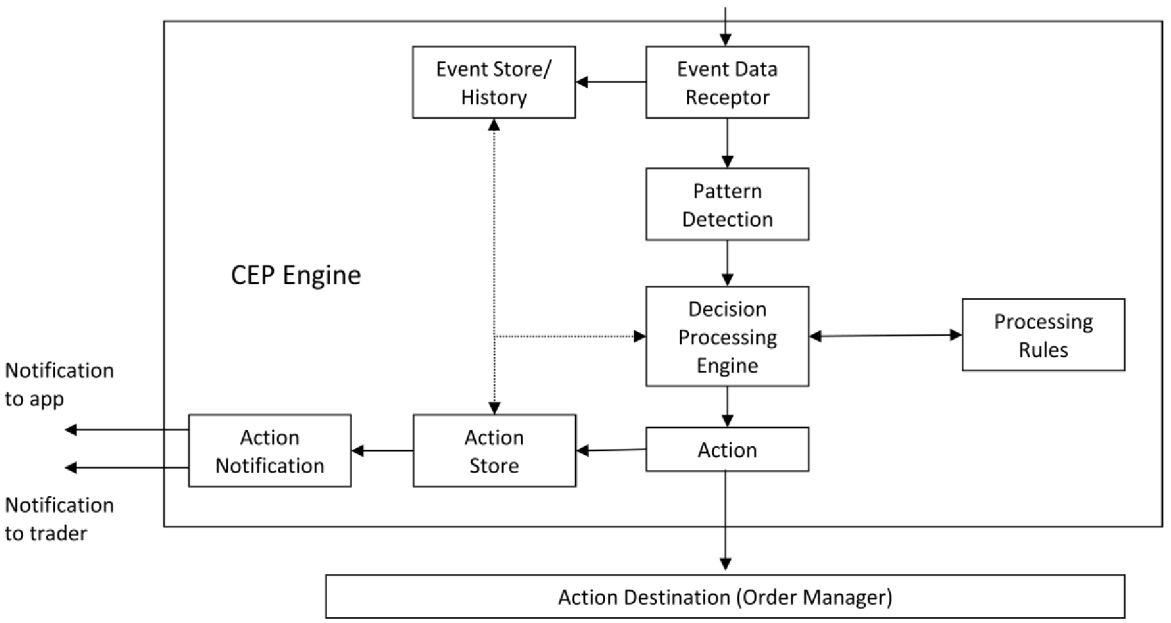


Fig 4 – Flow of events in CEP engine

4.3 Order Routing / Order Manager

The action notifications from the CEP engine are received by the order manager (OM). The

order manager receives such notifications typically from multiple CEP engines. This module is responsible for generating and managing orders to external destinations as well as for Risk management checks.

A single order manager typically manages orders for multiple segments. Since all orders would flow through this module, RMS checking is implemented at this stage before the order is generated. Depending on the segment and the settings it could use the FIX API or native API to send and receive orders.

In addition to above, the OM also maintains the state of the orders and manages the invitations.

Tap Server and Invitations

In the case of Non Neat systems, all interactive communication to the exchange is handled through a TAP server, which acts like an intermediary. Upon connecting to a TAP server, an invitation message is received with one or more invitations. For every invitation received, the OM can send one message to the exchange.

Since the OM handles multiple CEP engines, it also manages the contention for an invitation.

For example, if CEP1 and CEP2 send new order signals to the OM which has only one invitation, the OM would only be able to forward one of the order signals while keeping the other on wait until a fresh invitation is sent by the TAP server.

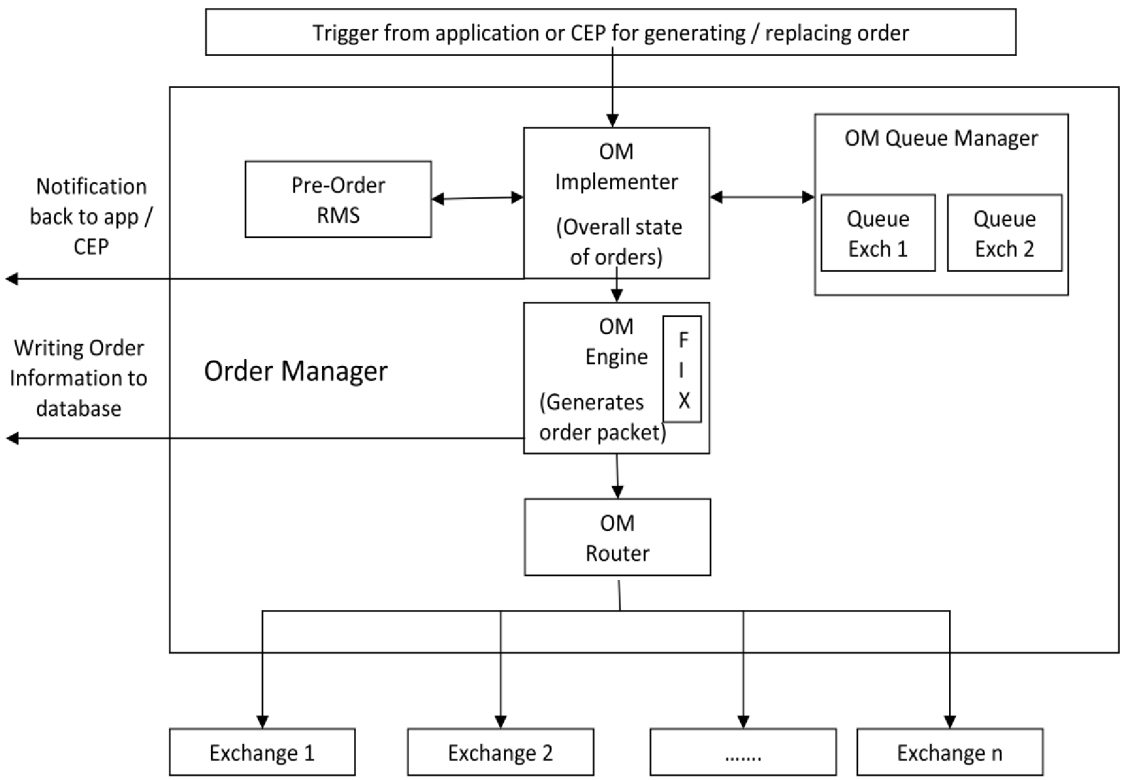


Fig 5 Flow of events in OM

4.4 New Trends – MultiTap

As mentioned in section 4.3 for every invitation received from the TAP server, the OM can send one message to the exchange. This could result in a bottleneck situation where the OM runs out of invitations. To circumvent this problem, NSE now provides a MultiTap server. Since every TAP server is associated with a network ip (that is provided by the exchange), multitap requires all the necessary ips to be configured on the same ethernet device using virtual ips. The Multitap server can then be configured to behave like multiple tap server processes (which earlier had to be run on different servers). This would mean the OM can now form multiple connections (one for each CTCL id on each of the TAP server processes), thus increasing the number of invitations and hence reducing the contention for invitations. Another added advantage of the multitap server is that the message rate (which is particular to the scenario being used to connect to the exchange) would also increase. The new message rate is effectively the sum of individual message rates across all the individual TAP ips.

4.5 Colocation

As discussed in the earlier sections, the advent of automated trading systems and high frequency trading systems led to a need for low latency trading architectures. One of the ways to reduce latency in a very big way is to move physically closer to the exchange. That means the signal generated by the OM for an order reaches the exchange faster. To cater to this requirement, co-location facilities (rack space for the trading server within the exchange) are offered.

The main advantages are

- Market data arrives at the server faster.
- Once the CEP engine communicates the decision to the OM, the message/order reaches the exchange faster.
- This also means the acknowledgements/rejects reach the server faster. Hence the next action can be taken much earlier inside the colocation than outside.
- In the event of a network error on a TBT or bucket TBT connection, sync up with the offline server is much faster upon reconnection from inside the colocation.
- TBT connectivity + interactive connectivity to different segments are available on the same physical line as against having a separate line for TBT data of each segment outside.

4.6 Trading Setup

Typically trading setups can be classified into two broad types: Colocation setups and non-

colocation setups. In either case, the application typically runs in remote location (on the trader's desktop). However, as discussed above, the category in which the trading setup would fall would depend on where the heart of the system i.e., the CEP engine and the OM (collectively referred to as the Trading server) are running. For colocation setups, the trading server is in colocation and similarly, for non-colocation setups, it is typically located in a data centre.

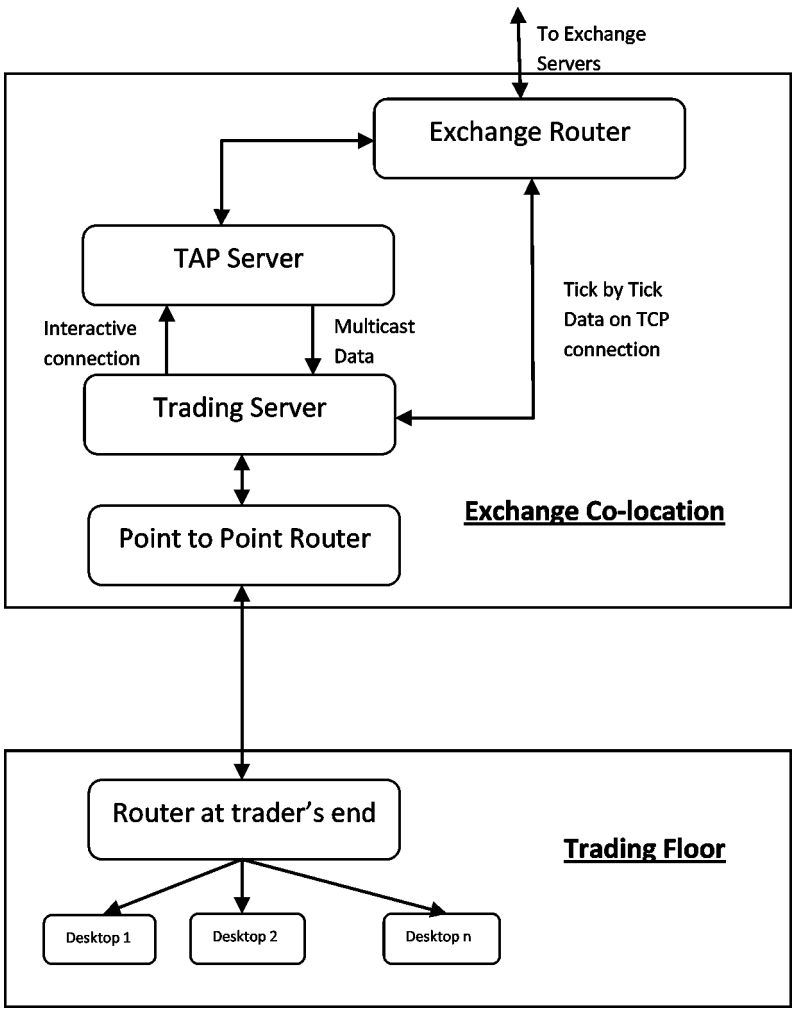


Fig. 6: Architecture of typical trading setup inside exchange co-location

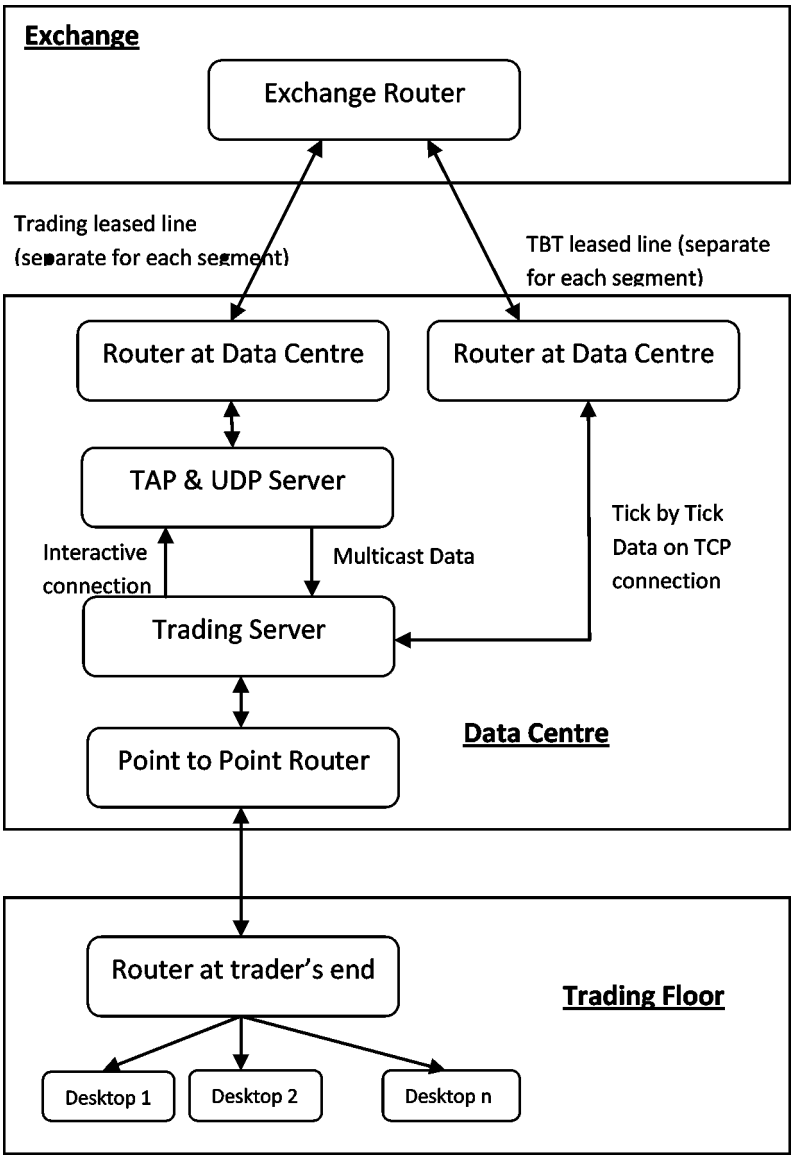


Fig. 7: Architecture of typical trading setup in data centre

4.7 Smart Order Routing (SOR)

The Securities and Exchange Board of India (SEBI) has approved SOR facility since August 2010. Using this facility, the broker trading servers (CEPs) could choose execution destination based on factors like price, etc that the broker seems fit.

The advent of SOR has led to the following changes

- The OM router now handles multiple locations.
- The market data from different destinations now is normalized into one standard format for the use of CEP.
- Communication via standard protocols like FIX gaining popularity unless native API offers significant latency advantages.

Following diagram showcases these changes

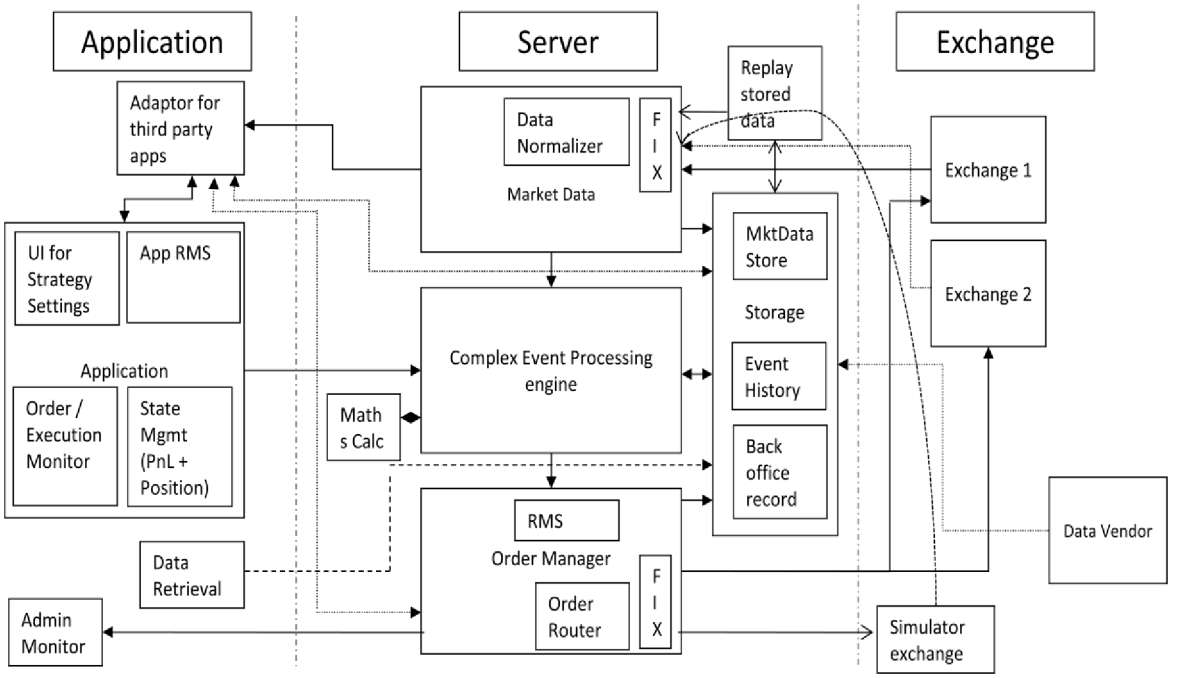


Fig 8: OM connects to multiple destinations.

4.8 Connectivity Options

There are two types of communication options available for trading members.

- VSAT (Very Small aperture terminal) – satellite based wireless communication
- Leased Line (wired terrestrial based communication)

The trading member needs to choose a scenario based on categories mentioned below

	A category	B category	C category	T category
Message rate	40 messages/ sec	100 messages/ sec	200 messages/ sec	N.A
Bandwidth	2Mbps	2Mbps	2Mbps	2Mbps
Market Data	Available but multicast only	N.A	N,A	Available but Tick by tick connection only
User ids	20 shared between CM and FO and 10 in CD.	50 shared between CM and FO and 10 in CD.	100 ids shared between all segments	N.A

	A category	B category	C category	T category
Scenarios	A1 – single VSAT A2 – Single leased line A3 – Single leased line with VSAT as backup A4 – Dual leased lines to one or two POPs A5 – Dual leased lines and VSAT as backup	B1 – Single leased line B2 – Dual leased line to one or two POPs	C1 – Single Leased Line C2- Dual leased lines to one or two POPs.	T1- single leased line T2 – Dual leased lines to one or two POPs.

Currently Indian exchanges enable Algorithmic Trading only on Leased Lines. Algorithmic trading is not allowed on VSAT or Internet Based Trading (IBT)

In addition to the above scenarios:

In the case of NEAT terminal – Every approved user is assigned to a branch id. For every 5 NEAT users under a branch id, there is a requirement for on valid NCFM certification.

In the case of Non-NEAT CTCL terminal – each location is assigned a branch ID which is contained in a 12 digit CTCL ID (apart from the three digits that explains the type of trading/ order). For every 5 CTCL ids in a branch id, 1 user should be NCFM certified.

Self Assessment

- Market data pattern detection and decision making happens in the
  - **CEP block**
  - OM block
  - Application block
  - Algorithmic trading platform

- Risk management is handled in the
  - **Order Manager and the application block both**
  - Order Manager
  - Complex Event Processing block
  - Complex Event Processing block and Order Manager

- The function of a simulator is to
  - Simulate the market data emanating from an exchange
  - **Simulate an exchange where orders could be sent (instead of sending to actual exchange)**
  - Simulate the performance of a strategy
  - Simulate the computational complexity of the algorithm before actual execution in real markets

Chapter 5 Risk management in Algorithmic Trading

Risk management in general is the process of managing the uncertainty associated with business operations – especially the undesirable ones. Since trading involves dealing with a lot of uncertainties related to the behaviour of the markets and market participants, risk management is a very critical task and department within trading operations. All instances of failures within trading firms are primarily linked to poor execution of risk management functions – mostly through under-estimation of extent of undesirable outcome; or the failure to identify certain factors which might lead to undesirable outcomes; or improper adherence towards risk management processes.

Operationally, automated trading is more complicated than non-automated trading – technological complications get added to trading related complexities. To ensure the proper functioning of the automated trading system, a lot of different technological components must interact with each other in real time – often this becomes a complex web of complicated linkages between different components of the automated trading system.

Since, from an operational perspective, automated trading is much more complicated as compared to non-automated trading, the uncertainties involved with the proper execution of automated trading are also higher.

In the sections that follow, we will look at risk management for trading operations at a holistic level. We will then look at risk management processes which are specific to automated trading.

5.1 Different Stages involved in Risk Management

The following are the different stages of the risk management process

1) Setting risk management structures & policies

2) Identifying sources of risk

3) Evaluating different risk components

4) Establishing risk appetite & setting risk limits

5) Designing systems with strict adherence to risk controls

Stage I: Setting risk management structures & policies

This is the first stage within risk management. This in turn involves the following activities:

i. Setting up a dedicated team of professional for the risk management department

ii. Separating the trading department from the risk management department – i.e. there should be no conflict of interest. The incentives of the risk management department should not be based on the trading profits as this will incentivize the risk management department to allow more trading risks.

iii. Providing full autonomy and empowerment to the risk management department to oversee trading activities. Given that even minor breaches of risk policies have the potential to cause huge losses in a very short duration itself, therefore the risk management team should be provided ample and direct empowerment to raise the red flag and stop trading activities as and when they deem necessary

iv. There should be a proper process oriented system for introducing new products, trading strategies and operations. Such a process oriented system will ensure that all the checks and balances are performed and known pitfalls addressed while embarking on anything new

Stage II: Identifying sources of risk

After creating the systems in place, the risk management department should try to create an exhaustive list of all risks against which they should protect the firm. The risks can usually be classified into the following categories:

i. Market Risks

(Risks arising from change in prices of securities in which the firm holds some position)

ii. Credit / Counter-party Risks

(Risks arising from failure of counter-party to meet obligations and commitments)

iii. Financing Risks

(Risks associated with the necessity to finance monetary requirements for normal operations)

iv. Regulatory Risks

(Risks associated with change in rules and regulations)

v. Liquidity Risks (Exogenous & endogenous)

(Risk of loss because of inability to perform a trade owing to absence of enough liquidity in the exchange at favourable levels. Moreover, additional losses also happen due to the necessity to pay the bid-ask spread while doing a trade. Furthermore, while trading huge quantities in a particular direction, the trade itself causes the market prices to move against the direction of the trade)

vi. Operational Risks - Systems, Mechanical, Criminal, Natural disaster, Terrorism, etc

(Risks associated with normal day to day operations – like proper working of the technology systems, physical security, political risks, etc. It can also cover risks like fraud, legal risks, etc)

Stage III: Evaluating risk components

The next stage involves designing methodologies to quantify current statuses so that the current situation can be monitored with respect to risk concerns.

i. Market Risks :

Market Risk can be evaluated using either sensitivity analysis or by using VaR analysis & Stress tests. In sensitivity analysis, the total exposure of the firm to different market risk conditions (like vega exposure for change in volatility, exposure, etc) are evaluated. For different scenario conditions, the profit/loss of the trading firm is then calculated.

In case of VaR analysis, the amount of loss with a threshold probability is set as a threshold.

In case of Stress test, various extreme case scenarios are analyzed and the situation of the firm checked in those extreme case situations.

1. Sensitivity Analysis
    a. Total Greeks, Dividend, Currency, Commodity, Interest Rate , Sector-wise, Geography-wise exposures
    b. What-if scenario analysis
2. VaR analysis
3. Stress tests

ii. Credit / Counter-party Risks :

Most firms use a score-card approach to ensure that exposure to different counter-parties is within a limit. These score-cards could use the ratings of independent third-party rating agencies to determine limits to be assigned for each counter party

A common methodology is to use the IRB method proposed under Basel II which is built on top of the Jarrow Turnbull model.

iii. Financing Risk

The risk has to be assessed on two fronts: (i) rho position of the firm (ii) exposure to shift in yield curve.

iv. Regulatory risk

This can be difficult to quantify and evaluate. A best attempt can be done to anticipate future change in regulations on the basis of news analysis and historical precedent.

Some of the common regulation based risks involve:

- Short Selling Ban
- Margin Increase
- New Taxes / Change in tax rates
- Ban on trading in certain class of securities

v. Liquidity Risks

The risks associated with loss of liquidity is measured using Liquidity adjusted VaR

L-VaR = VaR + Exogenous Liquidity Cost (worst expected divergence of bid-ask spread from fair value)

vi. Operational Risks (Systems, Mechanical, Criminal, Natural, Terrorism, etc)

The current status of the system has to be checked to ensure that the system is not operating under stretched conditions. This involves checking the following the system under the following categories:

Systems:

1. Robustness of the entire system – the ability of the trading systems and processes to handle stress situations
2. System Load handling capacity – the current load of the trading systems and maximum possible load on the systems and processes
3. Maximum order flow before system detects failure – the minimum time required to detect failures should be tested from time to time

Criminal:

1. Accessibility and security of key resources – the number of access points, number of people with access controls, etc
2. Fraudulent activities prevention checks

Natural Disaster and Terrorism:

1. This would involve verifying vulnerability of operations to such external risks. These can be quantified using a scorecard approach (similar to the approach used by insurance and actuarial firms). Moreover disaster recovery also involves

creating a backup of current operations in another location. This risk metric should be checked from time to time on the basis of readiness to shift to recovery location.

Stage IV: Setting risk limits

After having devised methodologies to evaluate the current status of the operations with respect to risk metrics, the next stage involves setting controls which will protect the operations against negative outcomes

i. Market Risks

Having defined ways to measure exposure to market risks on different metrics, limits should be set on trading positions to ensure that the following exposures are within limits:

- Total cash exposure
- Exposure to geography
- Exposure to sector
- Exposure to asset class
- Exposure to assignment / delivery risks (settlement risks)
- Settlement Type (future vs. cash)
- Exposure to interest rates
- Exposure to exchange rates

ii. Credit / Counter-party Risks

Setting total possible credit limit per counter party , per counter party category (say all counter parties from a particular geography, or all counter parties with similar credit rating) and overall credit at risk

iii. Financing Risks

Total rho exposure of the firm should be fixed at an upper limit

Moreover exposure per segment of the yield curve should also be fixed at an upper limit.

iv. Regulatory Risks

Stock borrowing should be limited to a fixed value to offset risks of ban on short-selling

Likewise, for rules increasing margin requirements, etc – limits on position sizes should be set

v. *Liquidity Risks (Exogenous & endogenous)*

Liquidity adjusted VaR for the firm should not fall outside a predefined limit

vi. *Operational Risks - Systems, Mechanical, Criminal, Natural, Terrorism, etc*

The following limits should be set

- Systems:
  - Max exposure per strategy
  - Max orders in a fixed time frame (per second in case of automated trading)
  - Max orders in a day
  - Max exposure per application
  - P&L fluctuation per application
  - Price Range check
  - Max order size
  - Max Value Traded
  - Net Value of portfolio
- Criminal/Fraud/ Theft, etc:
  - Access Control
  - Transparency of operations
  - Rotation of team members
  - Audit (internal & external)
  - Centralized P&L reconciliation
  - Independent verification of price to pricing models
  - Online Infiltration & Virus Protection

Stage V: Designing systems with strict adherence to risk controls

The entire risk management is still incomplete after determining all the sources of risk, defining the ways to calculate these risks and then setting limits on those risk exposures. The entire process will only be completed after the establishment of a system which provides the ability to monitor the operations in real-time and control all operations from a centralized system.

Therefore the following will need to be established:

- Centralized system which monitors all trading activities in real-time
  - Summarizes net positions exposures to different risk categories (different market risks, credit risk, financing risk, etc)
  - Displays overall system load & performance
- Centralized control of all trading operation
- Pre trade controls

5.2 Risk Management Specific to High Frequency & Algorithmic Trading

Risk management for automated and high frequency trading is a more critical and complicated process. The following characteristics of automated trading make risk management even more vital as well as complex:

i) Orders flow out of the trading system on their own on the basis of pre-defined triggers and parameters – 'without human control'

ii) Because a tremendous number of orders can flow out of the trading system in very rapid time in case of an error, therefore trading portfolio positions could reach dangerous levels in no time – even before a human being can realize (and respond), tremendous damage would have already been done

iii) Higher reliance on technology for this method of trading implies increased sys-ops risk. An automated trading system is composed of a number of different components linked together – any single link between two components not working in perfect order will wreck havoc

iv) Traders now have to keep technological complexities in mind while trading the financial markets – a proper understanding of the algorithmic black box is necessary for traders and therefore exposure to technology for financial professionals involved in trading is required.

To give an indication into the new types of errors which can happen only with automated trading systems, imagine the situation when the market data price feed from the exchange goes down – the algorithm will calculate and keep sending orders based on stale data. The reasons why the market data price feed is not working could again be traced back to a variety of possibilities – physical disconnection, software disconnection from the exchange, software crashes, etc.

- Risks specific to automated trading can be classified into the following categories:
  - Access

    These are related to ensuring that the current system connectivity in place and working properly
  - Consistency

    This involves ensuring that the processes are working in sync and in real time (i.e. ensuring that the market data and the calculations are not delayed significantly)
  - Quality

    This involves ensuring that the quality of the data is proper and the trading system is not operating on stale and garbage data.
  - Algorithm

    Here we need to validate the robustness as well as the correctness of the trading algorithm
  - Technology

    The network, operating system and hardware involved with the automated trading system should be monitored and checked
  - Scalability

    Since scaling an automated trading system is very easy - a strategy tested on one underlying only has to be executed for multiple underlying. However, the system might not work well when scaled up.
- Risks specific to automated trading are handled pre-order (i.e. before the order has flowed out of the trading system) and not post-trade. There are two main areas where these risks are checked
  - Within the trading application
  - In the Order Management System (before generating the order)

RISK		Methodology
Access	Connectivity to an exchange goes down	Sending heart-beats to check if the connectivity is up
	Exchange disconnects you	Sending heart-beats to check if the connectivity is up

RISK		Methodology
	Network issue	Hardware, Operating System , ping to the router, ping time to the router
Consistency	Market Data is stale	Validating Time-stamp of market data with current time
	Trading strategies are running in real-time (huge processing time might result in strategy responding much later after the event in the market)	Time-stamp of analytics compared to current time
	Order Manager adaptor is responding in real time	Time-stamp
Quality	Market - data is garbled	Market Data adaptor should typically handle it. Moreover the trading application should reject such data
	Loss of liquidity during high-volatility periods – during such periods the market data used to calculate strategy values as well as strategy orders will be grossly miscalculated because the underlying prices itself are not properly available	The trading application should stop the strategy when the market liquidity has dried below a particular level.
Algorithmic	Margin breached	The Order Manager should not allow the system to send orders which increase the margin usage beyond a particular threshold
	Exposure limit set by exchange	Exposure limit should be set in the system
	Risk limits exceeded	Check for acknowledgements before sending order

RISK		Methodology
	Incorrect strategy setting leading to continual bad trades	P&L fluctuation check – if the P&L of the strategy drops a lot, then that could mean that a lot of bad trades are happening
	-do-	Order release (throttle) rate – if a strategy setting is wrong, then the strategy will end up sending orders at wrong levels which will then be traded against by other market participants. Therefore one metric is to measure the number of orders flowing out of the system – in case this is too high, then it could be the result of a wrong strategy
	-do-	Fat finger settings check – the trading application should not allow the trader to input values which are way different from expected range of values
	-do-	Max Value Traded. Wrong parameters will lead to lots of wrong trades – this metric will ensure that the number of wrong trades is stopped after a traded value reached a limit
	Incorrect order generation	Price range check – orders can only flow out of the system if the order prices do not vary too much from the market levels
	Order throttle	Exchange reject limit – the number of orders that can be sent per second.
Technology	Hard disk space	Independent check
	Virus /Trojan	Firewall, Anti-virus
	System Crash	Operating System
	Application crash	Heart-beat to check application
	Protocol Mismatch	Third-party software compatibility check

Mandatory checks required by the exchanges and regulators for automated trading systems

Basic RMS description:

Manual trading disabled: Manual orders are disabled for auto-trading systems

Trade Price Protection Limit: Algorithmic orders should not be released in breach of the bad trade price as defined by the Exchange for the security in respective segments

Quantity Freeze Limit: For each instrument an order quantity size is defined by the exchange. Algo order should not breach this limit.

Price Range Check: Order should not breach the circuit limit (daily price range) of an instrument

FII restricted list: FIIs cannot trade in a select set of stocks (RBI directed)

Market Wide Protection Limit: Cannot trade derivatives to increase Open Interest beyond a pre-defined threshold

Shares available for selling: Overnight long position that is available per share for selling

Automated Trading enabled: Automated trading to be enabled for a select list of instruments only

Index change check: The system cannot send Buy/Sell orders if the index has gone up/ down beyond a certain percentage point.

Client Position Limit: Algo orders should not be released in breach of position limit as defined by the trading member for the client.

Margin Limit: If a threshold of the available margin is reached, then the application should not send orders to increase the position further

Exposure Limit Check: Orders should not be released in breach of exposure limit as defined by the trading member for the client.

Order Value: Exchange prescribes Maximum Value any single order can have. System should incorporate check so that any given single order should not exceed that value.

Self Assessment:

- What kind of risk is to be managed for Portfolio Gamma exposure (i.e. Change in Delta)?
  - Credit Risk
  - **Market Risk**
  - Financing Risk
  - Regulatory Risk

- Which of the following is not a type of risk associated specifically with algorithmic trading?
  - Access
  - Consistency
  - **Novelty**
  - Quality

- Which of these is not a mandatory check required by the exchange for running automated trading systems
  - Trade Price Protection Limit
  - Price Range Check
  - Market Wide Protection Limit
  - **Value at Risk check**

- Loss of liquidity during periods of high volatility would be classified under which category of algorithmic trading specific risk?
  - Access
  - **Quality**
  - Consistency
  - Market

Chapter 6 Audit and Compliance process

The advent of algorithm had posed new challenges for compliances, which in turns paved path for the introduction of new regulation to prevent participants to indulge in malpractices. SEBI has advised exchanges to conduct audit of member-brokers periodically to ascertain proper conduct on their part.

6.1 International Organization of Securities Commissions

International Organization of Securities Commissions (IOSCO) was formed in 1983. It was the expansion of inter-American regional association that was created in 1974. IOSCO is an association of organizations that regulate the world's securities and futures markets, i.e. an association of different securities market regulators (like SEBI in India) across the globe. It has members from more than 100 different countries that regulate more than 90% of the world's securities markets.

There are three different categories of Membership for IOSCO members:

1. Ordinary Members: They are the primary regulators of securities and/or futures markets in a jurisdiction and each member has one vote. Securities Exchange Board of India (SEBI) is an ordinary member in IOSCO.
2. Associate Members: In case there is more than one regulator in a jurisdiction, then the regulator(s) other than the primary regulator are listed here. Though associate members do not have any voting rights but they can be members of the Presidents' Committee. Forward Market Commission (FMC) is an associate member of IOSCO.
3. Affiliate Members: This category includes the exchanges, industry associations, etc. Affiliate members do not have voting rights and cannot be a part of Executive committee or Presidents' Committee. Most of the leading exchanges of India are all affiliate members of IOSCO.

IOSCO's Technical committee provided the principles for Direct Electronic Access (DEA) to Markets in August 2010. IOSCO laid down the following principles for Pre-Conditions for DEA, Information Flow and Adequate Systems and Controls:

1. Pre Conditions for DEA
    a. Principle 1: Minimum Customer Standards

        The market authorities should have rules in place that requires intermediaries to have minimum customer standards like appropriate financial resources and procedures

b. Principle 2: Legally Binding Agreement

There should be a recorded, legally binding contract between the intermediary and the DEA customer, the nature and detail of which should be appropriate to the nature of the service provided. Each market should consider whether it is appropriate to have a legally binding contract or other relationship between itself and the DEA customer.

c. Principle 3: Intermediary's Responsibility for Trades

An intermediary retains ultimate responsibility for all orders under its authority, and for compliance of such orders with all regulatory requirements and market rules.

2. Information Flow

a. Principle 4: Customer Identification

Intermediaries should disclose to market authorities upon request and in a timely manner the identity of their DEA customers in order to facilitate market surveillance. In those jurisdictions where sub-delegation is permitted, the intermediary also has such responsibility to the market authorities with respect to any sub-delegates.

b. Principle 5: Pre and Post-Trade Information

Markets should provide member firms with access to relevant pre- and post-trade information (on a real time basis) to enable these firms to implement appropriate monitoring and risk management controls.

3. Adequate Systems and Controls

a. Principle 6: Markets

A market should not permit DEA unless there are in place effective systems and controls reasonably designed to enable the management of risk with regard to fair and orderly trading including, in particular, automated pre-trade controls that enable intermediaries to implement appropriate trading limits.

b. Principle 7: Intermediaries

Intermediaries (including, as appropriate, clearing firms) should use controls, including automated pre-trade controls, which can limit or prevent a DEA Customer from placing an order that exceeds a relevant intermediary's existing position or credit limits.

c. Principle 8: Adequacy of Systems

Intermediaries (including clearing firms) and markets should have adequate operational and technical capabilities to manage appropriately the risks posed by DEA.

6.2 Auditing Process and Requirements (As defined by NSE for member-broker)

General audit requirement are as follows:

- The Half yearly System Audit should be conducted only for Algorithmic trading facility approved for the Trading Member through Exchange empanelled system auditors.
- Audit Report for Algorithmic facility is required to be submitted to the Exchange through NSE ENIT
- It is mandatory for the auditors to provide ratings /remarks / recommendation on all the points wherever not complied. Additionally, auditors are required to give ratings 'Strong', 'Medium' and 'Weak' on each broad areas of audit.
- Auditors are required to provide the list of all the algorithmic strategies approved for the members and audited by them on their letter head.
- Members are required fill up the electronic summary sheet and upload the details of all the algorithmic strategies in the template provided on ENIT system

6.3 SEBI Recommendations on Audit

SEBI has been advising and setting broad guidelines on Algorithmic Trading from time to time. In the Circular No.CIR/MRD/DP/09/2012 dated March 30, 2012 on Broad guidelines on Algorithmic Trading. These guidelines are as follows:

Guidelines for Exchanges:

Stock exchanges to ensure the following while permitting algorithmic trading:

(i) The stock exchange shall have arrangements, procedures and system capability to manage the load on their systems in such a manner so as to achieve consistent response time to all stock brokers. The stock exchange shall continuously study the performance of its systems and, if necessary, undertake system up gradation, including periodic up gradation of its surveillance system, in order to keep pace with the speed of trade and volume of data that may arise through algorithmic trading.

(ii) In order to ensure maintenance of orderly trading in the market, stock exchange shall put in place effective economic disincentives with regard to high daily order-to-trade

ratio of algorithmic trading orders of the stock broker. Further, the stock exchange shall put in place monitoring systems to identify and initiate measures to impede any possible instances of order flooding by algorithms.

(iii) The stock exchange may seek details of trading strategies implemented through algorithmic trading for such purposes viz. inquiry, surveillance, investigation, etc.

(iv) Terminals of the stock broker that are disabled upon exhaustion of collaterals shall be enabled manually by the stock exchange in accordance with its risk management procedures.

(v) The stock exchange shall include a report on algorithmic trading on the stock exchange in the Monthly Development Report (MDR) submitted to SEBI inter-alia incorporating turnover details of algorithmic trading, algorithmic trading as percentage of total trading, number of stock brokers / clients using algorithmic trading, action taken in respect of dysfunctional algorithms, status of grievances, if any, received and processed, etc.

(vi) The stock exchange shall synchronize its system clock with the atomic clock before the start of market such that its clock has precision of atleast one microsecond and accuracy of atleast +/- one millisecond.

(vii) Stock exchange shall ensure that the stock broker shall provide the facility of algorithmic trading only upon the prior permission of the stock exchange. Stock exchange shall subject the systems of the stock broker to initial conformance tests to ensure that the checks mentioned below are in place and that the stock broker's system facilitate orderly trading and integrity of the securities market. Further, the stock exchange shall suitably schedule such conformance tests and thereafter, convey the outcome of the test to the stock broker.

For stock brokers already providing algorithmic trading facility, the stock exchange shall ensure that the specified risk controls are implemented by the stock broker.

(viii) The stock broker, desirous of placing orders generated using algorithms, shall submit to the respective stock exchange an undertaking that -

- The stock broker has proper procedures, systems and technical capability to carry out trading through the use of algorithms.
- The stock broker has procedures and arrangements to safeguard algorithms from misuse or unauthorized access.
- The stock broker has real-time monitoring systems to identify algorithms that may not behave as expected. Stock broker shall keep stock exchange informed of such incidents immediately.

- The stock broker shall maintain logs of all trading activities to facilitate audit trail. The stock broker shall maintain record of control parameters, orders, trades and data points emanating from trades executed through algorithm trading.
- The stock broker shall inform the stock exchange on any modification or change to the approved algorithms or systems used for algorithms.

In addition to above guidelines, in the Circular No.CIR/MRD/DP/16/2013 dated May 31, 2013, SEBI laid out additional guidelines pertaining to Audit.

1: The stock brokers/ trading members that provide the facility of algorithmic trading shall subject their algorithmic trading system to a system audit every six months in order to ensure that the requirements prescribed by SEBI / stock exchanges with regard to algorithmic trading are effectively implemented

1.1: Such system audit of algorithmic trading system shall be undertaken by a system auditor who possesses any of the following certifications:

a) CISA (Certified Information System Auditors) from ISACA;

b) DISA (Post Qualification Certification in Information Systems Audit) from Institute of Chartered Accountants of India (ICAI);

c) CISM (Certified Information Securities Manager) from ISACA;

d) CISSP (Certified Information Systems Security Professional) from International Information Systems Security Certification Consortium, commonly known as (ISC)

1.2: Deficiencies or issues identified during the process of system audit of trading algorithm / software shall be reported by the stock broker / trading member to the stock exchange immediately on completion of the system audit.

1.3: In case of serious deficiencies / issues or failure of the stock broker / trading member to take satisfactory corrective action, the stock exchange shall not allow the stock broker/ trading member to use the trading software till deficiencies / issues with the trading software are rectified and a satisfactory system audit report is submitted to the stock exchange. Stock exchanges may also consider imposing suitable penalties in case of failure of the stock broker/ trading member to take satisfactory corrective action to its system within the time-period specified by the stock exchanges.

6.4 Exchange Audits

The Exchange audit process shall broadly cover the following aspects:

- Approved features and system parameters implemented in the trading system

- Adequacy of input, processing and output controls should be tested
- Adequacy of the application security should be audited
- Event logging and system monitoring
- Robust Password management standards
- Network management and controls
- Backup systems and procedures
- Business continuity and disaster recovery plan
- Proper Documentation for system processes
- Security features such as access control, network firewalls and virus protection should be actively managed

The stock exchange shall ensure that all algorithmic orders are necessarily routed through broker servers located in India and the stock exchange has appropriate risk controls mechanism to address the risk emanating from algorithmic orders and trades. The minimum order-level risk controls shall include the following:

a. Price check: The price quoted by the order shall not violate the price bands defined by the exchange for the security. For securities that do not have price bands, dummy filters shall be brought into effective use to serve as an early warning system to detect sudden surge in prices.

b. Quantity Limit check: The quantity quoted in the order shall not violate the maximum permissible quantity per order as defined by the exchange for the security.

In the interest of orderly trading and market integrity, the stock exchange shall put in place a system to identify dysfunctional algorithms (i.e. algorithms leading to loop or runaway situation) and take suitable measures, including advising the member, to shut down such algorithms and remove any outstanding orders in the system that have emanated from such dysfunctional algorithms. Further, in exigency, the stock exchange should be in a position to shut down the broker's terminal.

The stock broker, desirous of placing orders generated using algorithms, shall satisfy the stock exchange with regard to the implementation of the following minimum levels of risk controls at its end -

(i) Price check– Algorithmic trading orders shall not be released in breach of the price bands defined by the exchange for the security.

(ii) Quantity check– Algorithmic trading orders shall not be released in breach of the quantity limit as defined by the exchange for the security.

(iii) Order Value check- Algorithmic trading orders shall not be released in breach of the 'value per order' as defined by the stock exchanges.

(iv) Cumulative Open Order Value check– The individual client level cumulative open order value check, may be prescribed by the broker for the clients. Cumulative Open Order Value for a client is the total value of its unexecuted orders released from the stock broker system.

(v) Automated Execution check– An algorithm shall account for all executed, un-executed and unconfirmed orders, placed by it before releasing further order(s). Further, the algorithmic trading system shall have pre-defined parameters for an automatic stoppage in the event of algorithmic execution leading to a loop or a runaway situation.

(vi) All algorithmic orders are tagged with a unique identifier provided by the stock exchange in order to establish audit trail.

6.5 Technology and System Audit

System Audit includes the following main areas:

- Risk Management
- Security Policy and Implementation
- Capacity Management
- Disaster Recovery and Backups
- Vulnerability

The following gives a detailed account of the areas of system audit:

Location Confirmation

- Complete address of broker's server routing Algorithm orders to the Exchange trading system

Risk Management

The installed system is capable of assessing the risk as soon as the algorithm orders are generated and informs the user of rejection of the order (if any) within a reasonable period.

Risk Management Tools:

- Should allow for risk management of the orders placed and online risk monitoring of the orders being placed.
- The system has functionality for mandatorily routing of orders generated by algorithm through the automated risk management system and only those orders that are within

the parameters specified in the risk management systems are allowed to be released to exchange trading system.

- The risk management system has following minimum levels of risk controls functionality and only algorithm orders that are within the parameters specified by the risk management systems are allowed to be placed.
  - Individual Order Level
    - Quantity Limits
    - Price Range checks
    - Trade price protection checks
    - Order Value Checks(Order should not exceed the limit specified by the Exchange)
    - Market price protection
    - Spread order Quantity and Value Limit
  - Client Level
    - Cumulative Open Order Value Check
    - Automated Execution check
    - Net position v/s available margins
    - RBI violation checks for FII restricted stocks
    - Market-wide Position Limits (MWPL) violation checks
    - Position limit checks
    - Trading limit checks
    - Exposure limit checks at individual client level and at overall level for all clients
    - Branch value limit for each branch ID
    - Security wise limit for each user ID
    - Identifying dysfunctional algorithms
- Does system has functionality to specify values as unlimited for any risk controls listed above?
- Does the member have additional risk controls / policies to ensure smooth functioning of the algorithm?(if yes, please provide details)

Execution of Orders / Order Logic

The installed system provides a system based control facility over the order input process

- Order Numbering Methodology
- The system has an internal unique order numbering system.
- All orders generated by Algorithm system are offered to the market for matching and system does not have any order matching function resulting into cross trades.
- Whether algorithm orders are having unique flag/ tag as specified by the Exchange. All orders generated from algorithmic system are tagged with a unique identifier – 13th digit of NNF field is populated with 0.

Database Security

The system has sufficient controls over the access to and integrity of the database

- The access to the database is allowed only to authorized users / applications
- The database is hosted on a secure platform
- The database stores all the details of user ids activated for along with user names and passwords securely
- Frequency of antivirus patch updates

System Authentication

The system Authentication mechanism is as per the guidelines of the NSE

- The password policy / standard are documented
- The system allows access to only authorized users
- The system has a password mechanism which restricts access to authenticated users
- The system requests for identification and new password before login into the system
- The system has appropriate authority levels to ensure that the limits can be setup only by persons authorized by the risk / compliance manager

The installed system's Password features include

- The Password is masked at the time of entry
- System mandated changing of password when the user logs in for the first time
- Automatic disablement of the user on entering erroneous password on three consecutive occasions
- Automatic expiry of password on expiry of 14 calendar days

- System controls to ensure that the password is alphanumeric (preferably with one special character), instead of just being alphabets or just numerical
- System controls to ensure that the changed password cannot be the same as of the last password
- System controls to ensure that the Login id of the user and password should not be the same
- System controls to ensure that the Password should be of minimum six characters and not more than twelve characters
- System controls to ensure that the Password is encrypted at members end so that employees of the member cannot view the same at any point of time
- System control ensures Re-initialization of access on entering fresh passwords

System Backup

The Installed systems backup capability is adequate as per the requirements of the exchange for overcoming loss of product integrity.

- Are backups of the following system generated files maintained as per the exchange guidelines?
- At the server/gateway level
  - Database
  - Audit Trails
  - Reports
- At the user level
  - Logs
  - History
  - Reports
  - Audit Trails
  - Alert logs
- Does the audit trail capture the record of control parameters, orders, trades and data points emanating from trades executed through algorithm trading?
- Are backup procedures documented?
- Are backup logs maintained?
- Have the backups been verified and tested?

- Are the backup media stored safely in line with the risk involved?
- Are there any recovery procedures and have the same been tested?

Information Security

To ensure information security for the Organization in general and the system in particular policy and procedures as per the NSE requirements must be established, implemented and maintained.

- Whether installed systems & procedures are adequate to handle algorithm orders/ trades?
- Maintenance of User details: Whether details of users activated for algorithm facilities is maintained along with user name, unique identification of user, authorization levels.
- Does the organization's documented policy and procedures include the following policies and if so are they in line with the NSE requirements?
  - Information Security Policy
  - Password Policy
  - Network Security Policy
  - Application Software Policy
  - Backup Policy (data should be available for minimum 5 years)
  - Audit Trail Policy (data should be available for minimum 5 years)
- Whether all the documents are classified as per CIA(Confidentiality, Integrity and Availability)
- Does the organization follow any other policy or procedures or documented practices that are relevant?

Firewall

- Is a firewall implemented?
- Are all servers placed in a DMZ and segregated from other zones by using a firewall?
- Is there segregation between application and database servers?
- Are user and server zones segregated?
- Is specific port/service access granted on firewall by following a proper approval process?

Physical Security

- Physical Access Control

- Server Room/Network Room Security (Environmental Controls)
- Server Room/Network Room Security (UPS)
- Server Room/Network Room Security (HVAC)

System Records

The system and system records with respect to Risk Controls are maintained as prescribed by the Exchange

- The limits are setup after assessing the risks of the corresponding user ID and branch ID
- The limits are setup after taking into account the member's capital adequacy requirements
- All the limits are reviewed regularly and the limits in the system are up to date
- All the branch or user have got limits defined and that no user or branch in the system is having unlimited limits on the above stated parameters
- Daily record of these limits is preserved and shall be produced before the Exchange as and when the information is called for
- Compliance officer of the member has certified the above in the quarterly compliance certificate submitted to the Exchange

6.6 Compliance Requirements

In the circular, NSE/CMTR/21793 dated September 28, 2012, exchange laid out compliances requirements:

- The Algorithmic orders are routed through broker servers located in India.
- The system has the capabilities to monitor algorithms real-time to identify those algorithms that may not behave as expected and bring it to the notice of the Exchange immediately.
- The system maintains logs of all trading activities including record of control parameters, orders, trades and data points emanating from trades executed through algorithm trading to facilitate audit trail.
- The system releases further order(s) only after accounting for all executed, unexecuted and unconfirmed orders placed earlier. Further, system shall have pre-defined parameters for an automatic stoppage in the event of Algorithmic execution leading to a loop or a runaway situation.

- Any modifications / Change to the approved decision support tool / Algorithm to be effected only on prior approval of Exchange.
- All Algorithmic orders emanating from the system to be tagged with the unique identifier as specified by Exchange from time to time

System compliance requirement for Algorithmic Trading Facility on annual Basis:

Trading members who have obtained approval from Exchange for CTCL trading software (including all the applications that is CTCL, IBT, DMA, STWT and SOR) are required to submit to the Exchange the System Audit Report for the year ended March 31, every year, after getting the CTCL trading facility audited from certified auditor, independent of the empanelled vendors of the Exchange and/or Partners/Directors of the trading members. Members are required to submit the system audit report to the Exchange through NSE ENIT electronically on or before April 30.

System audit requirement for Algorithmic Trading Facility on half yearly Basis:

As part of half yearly compliance as mandated by SEBI, trading members who have obtained approval from Exchange for Algorithmic trading software are required to submit the System Audit Report for the half year ended March 31 (i.e. for the period from October 01 to March 31) and September 30 (i.e. for the period April 01 to September 30), after getting the Algorithmic trading facility audited from Exchange empanelled system auditors (CISA certified).

Self Assessment

- Audit is compulsory for
  - Exchange members who are providing brokerage services
  - Institutional brokers
  - **All members of the exchange**
  - Only those exchange members who are trading using algorithms

- The full form of CTCL is:
  - Centralized Trading and Clearing Limited
  - **Computer To Computer Link**
  - Computerized Trading Corporation Limited
  - Centralized Time Correction Link

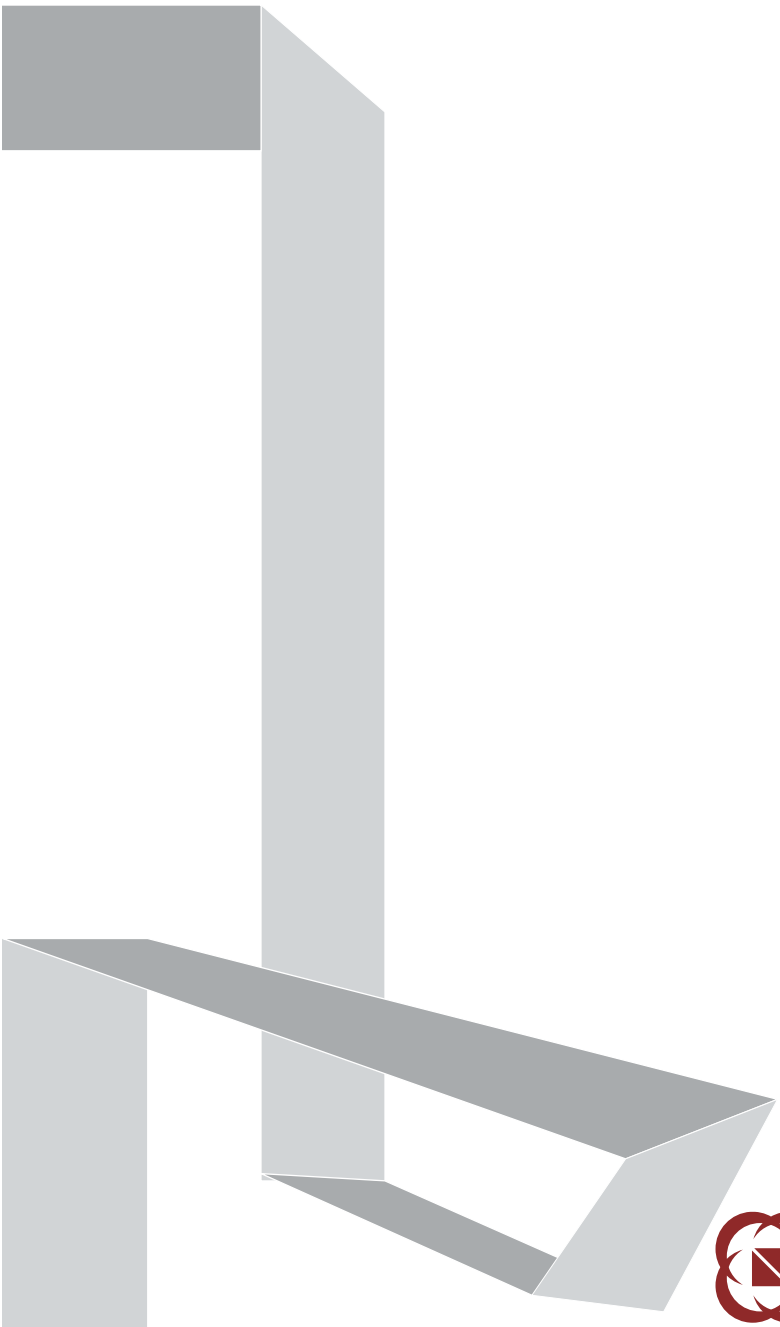
- Orders to be included in Audit trail are:
  - Executed orders only
  - Unexecuted orders only
  - **All orders**
  - All new orders only

- It is not possible to include market orders for cumulative open order value check.
  - True
  - **False**

- As per the prescribed back up policy, data should be available for at least:
  - 1 year
  - 3 years
  - **5 years**
  - 8 years

- Following type of trades are exempted from the audit compliance process:
  - Exchange member's proprietary trades on the exchange
  - Trades done by the client of exchange member
  - Trades done by the institutional client of the exchange member
  - **None of the above**

- A broker can route his trade from the servers located anywhere in the world but his head office has to be in India.
  - True
  - **False**



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