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Course Title

Trading and Technology:
An Information Systems Course Application

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6

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Adaptation Statement

- *This course is chapter 4 titled "Trading and Technology: An Information Systems Course Application" adapted from the book titled "Liquidity, Markets and Trading in Action, An Interdisciplinary Perspective", which can be downloaded for free from the following link: https://open.umn.edu/opentextbooks/textbooks/liquidity-markets-and-trading-in-action*

- *Check additional references and sources in the original document.*

- *This adaptation has reformatted the original text, and have replaced some images and figures to make the resulting whole more shareable. This adaptation has not significantly altered or updated the original text.*

- *Few modifications have been made for the purpose of presenting this course on this website.*

Trading and Technology: An Information Systems Course Application

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Chapter 1 focuses on microeconomics. In it we present the Capital Asset Pricing Model (CAPM), a theoretical formulation that shows, without reference to a "real-world" marketplace where shares are traded, how prices are set in a frictionless, zero trading cost environment. At the end of Chapter 1, we introduce friction in a minimalistic way and show that doing so perturbs market outcomes. In Chap. 2, which focuses on finance, we go deeper into the realities of price determination and trading in a non-frictionless environment. In so doing, we show that the structure of a marketplace does indeed matter. In this chapter, we drill down and examine the capabilities IT provides. We examine the realities of a non-frictionless market in order to focus on how technology can enhance the efficiency of an actual marketplace. Difficult market design issues arise when an actual computerized trading mechanism is developed and operated. As IT professionals know, a production system is a big step forward from a conceptual design or a prototype. That is the direction in which we now head.

Technology has transformed trading and provided new computerized marketplaces that bring buyers and sellers of securities together efficiently and transparently. Gone are loud trading floors and a flurry of paper tickets to process. Today, software mediates the submission and prioritization of buy and sell orders, and stock exchange matching engines facilitate trades with millisecond timing. Most trading orders are now submitted by software using complex algorithms that respond to live market data. Computer technologies underpin the essential functioning of today's markets from price dissemination, to order matching, to the clearing and settling of trades.

Banking institutions, innovators, and entrepreneurs continually develop new systems and technologies to meet the needs of traders and to enhance the operations of markets. Most recently, Distributed Ledger Technology (DLT) and Blockchain applications,[1] more than could previously be imagined, offer exciting opportunities

[1] A blockchain is a data structure (i.e., data in a predefined format) used in distributed ledgers that store and transmit packages of data called "blocks" that are "chained" together. A distributed ledger shares blockchain data across a network of computers accessed by different network partici-

D. Ozenbas et al., *Liquidity, Markets and Trading in Action*, Classroom Companion: Business, https://doi.org/10.1007/978-3-030-74817-3_4

to radically change the operations of markets and widen access to trading venues and the safe settlement of transactions.

This chapter covers the foundational technologies that have been implemented (1) to create end user trading systems and online markets and (2) to computerize financial operations. Three key technologies – application software, database systems, and networks – power trading today, and participants in financial markets must understand them and their roles in supporting successful trading operations. Moreover, these technologies are often applied to create innovative market systems that are not merely incremental improvements to current practice, but that fundamentally disrupt the industry and establish new, leading firms. Think of how the ride-sharing firms Uber and Lyft have used IT and ubiquitous smartphones to disrupt the taxi and limousine industries and offer innovative new services.

Information systems students and skilled technology developers will have many types of jobs and career paths open to them in trading and the financial markets industry. They could be doing work for an active trading desk performing tasks that range from customizing software and collaborating with market data vendors to connectivity to the many data sources and market venues relied on today. Start-up ventures also need IS professionals to develop novel systems that revolutionize how a financial process (e.g., consolidating data and analyzing risk) is carried out to launch a new system to improve price discovery for difficult-to-trade securities. This chapter will be useful for information systems (I.S.) classes that emphasize applications of technology in banking or capital markets, or for a finance course that examines the technology operations and management challenges in a high tech industry such as the finance sector.

4.1 IT Innovations: Disruptive Versus Incremental

Innovations in the financial markets that are *disruptive* lead to new entrants challenging incumbent organizations and to a reordering of the players in the industry. An example is Nasdaq, which launched in the United States in 1971 as the first fully automated stock market. Its initial goal was to automate the daily "pink sheets" of indicative (non-firm) bid and ask quotes of small, over-the-counter stocks. Within several years, Nasdaq grew to rival the New York Stock Exchange (NYSE), in particular attracting the initial public offerings (IPOs) of many growth and technology stocks such as Apple (1980), Microsoft and Adobe (both 1986) and Dell (1988), that remained Nasdaq stocks in defiance of the existing Wall Street convention of listings moving to the more prestigious "Big Board" as soon as a company qualified for an NYSE listing.

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pants. Until recently ledgers were centralized and held by a controlling entity. Distributed Ledger Technology (DLT) is the set of approaches to recording and sharing data across multiple ledgers or data stores. DLT could have applications in securities market infrastructure and allow for transactions and data to be recorded and synchronized across a distributed network. Blockchains were first widely applied as the underlying technology of the cryptocurrency Bitcoin.

While disruptors like Nasdaq can displace established, market-leading institutions (OTC pink sheets) and capture market share from incumbent organizations, other technology innovations are *incremental* and support the business models of established firms or markets. The NYSE, for instance, developed its designated order turnaround (DOT) system for electronically routing small market orders of up to 2,000 shares to the trading floor in 1976. DOT expanded the market's capacity but retained the roles of NYSE floor traders. A second example is the launch in 1977 of the Society for Worldwide Interbank Financial Telecommunications (SWIFT) messaging service. Developed cooperatively by six major international banks, SWIFT operates a system for international money and security transfers. Today, SWIFT is a vast messaging network used by banks and other financial institutions to securely send and receive information, such as money transfer instructions. Rather than disrupting international money by bypassing the major banks, the SWIFT system enhanced the services its participating banks can offer their customers.

New technology innovations such as Blockchain can be applied in either incremental, "competence-enhancing" ways or in a disruptive, "competence-destroying" way. Financial institutions that are "Goliaths" prefer the incremental use of information technology (IT) that supports or improves their market position, while start-up firms are often "Davids" that want to win customers to a radically new approach to what the incumbent firms are offering. Bitcoin and Ethereum are the two most popular cryptocurrencies in 2021. As they are more widely adopted, what disruptive consequences can you imagine for established financial organizations?

In the next section of this chapter, we outline the information technologies (IT) that underpin markets and trading systems that have enhanced market transparency and improved efficiency. The section that follows will examine the economic impacts information systems have on financial markets and trading. This chapter will finish with examples of market participants and their technology tools.

4.2 IT Infrastructure for Financial Markets

Technologists refer to the "layers" of IT that are integrated to build an information system. The lowest layer is hardware and infrastructure such as servers, telecommunications equipment such as routers and switches, and data storage devices. On top of the hardware layer are shared systems such as databases and network directories. The top layer of the stack contains applications that enable users to perform business and financial market functions. At the bottom of the stack are the physical devices that process and store financial market data and that send and receive data over telecommunications networks (Fig. 4.1).

Layers of IT Infrastructure	Example components
Applications	– Software programs – End-user and Enterprise applications – Communications applications – Analytics and modeling
Shared services and common applications	– Network connectivity – Database management systems (DBMS) – Data and network address registries
Hardware components	– Physical computer servers – Data storage devices – Network cabling and routers – Security access firewalls – Other data center devices

Fig. 4.1 A simplified three-layer IT stack. Components in each layer perform defined, self-contained functions yet interact with the other components and other layers using common standards and established communications protocols

4.3 IT Support for the Economic Functions of Financial Markets

Financial markets perform three basic economic functions: consolidate buying and selling interests, enforce market rules that ensure fairness and promote trust, and connect investors to those who need capital to fund their business or public sector initiatives (e.g., road construction). The goal of technologists working in the capital markets industry is to perform these functions as cost efficiently and profitably as possible, in many cases, using off the shelf software rather than building costly customized systems from scratch.[2] The first market function to consider is bringing together buyers and sellers of securities, currencies, and derivative contracts and providing price and trading volume information.

Before the computer era, traders gathered on "open outcry" market floors, representing buyers and sellers and following the exchange's rules to discover prices and exchange ownership and cash. This concentration of activity was beneficial for investors since it maximized the chance of finding a counterparty and trading at competitively determined prices. As open outcry trading has been replaced by screen-based markets, real-time market information that was once accessible only to those on the trading floor is now widely available. By providing trading information and a process for price discovery for standardized instruments – stocks, bonds, foreign currency, and derivative products (futures and options) – markets play an important role in facilitating buying and selling. The effects of more information dissemination and reduced latency (from a trading decision to a completed trade) have enhanced liquidity and provided more trading choices to investors than they had when floor markets dominated.

[2] Off-the-shelf or hosted software is sold by IT vendors to financial firms as a more cost-effective solution compared to customized software that a firm might build for itself.

A second function of markets is to provide formal rules for setting prices and matching orders. For instance, a market order to sell arriving to an open outcry floor market would be required to trade at the highest available bid price; otherwise, a "trade-through" violation has occurred. As discussed in Chapter 2, a superior bid price that was traded through will lead to the seller receiving an inferior price. Most electronic order book markets execute limit orders according to "price-time" priority rules (the best priced orders arriving earliest will trade first). Enforcing rules and ensuring that participants' orders are treated fairly generates trust and can be explicitly coded into the order matching software of a computerized market. In addition, conflicts of interest and opportunities for fraud arise in markets, so investors require assurance that market information is valid and reliable. For instance, many markets prohibit "spoofing."[3]

Third, markets intermediate between the sources of capital (investors) and users of capital (companies and governments) and provide liquidity. This means that, for instance, an investor managing a fund that purchases a borrowing company's bonds does not need to hold the bonds until maturity. The buyer can reverse the decision by selling the bonds back to other buyers in the market. The liquidity of financial assets makes them more valuable than other assets that cannot be readily converted into cash (e.g., jewelry and houses). As markets have become more technologically advanced, more investors are willing to invest in businesses and can sell or buy to reflect their opinions and willingness to take on risk.[4]

4.4 Instruments and Market Data

Many things of value can be traded, and open-air marketplaces, souks, and storefronts have existed since the dawn of civilization. Financial markets facilitate the transfer of money into financial instruments, which are issued or sold to investors by companies to raise capital or by government bodies to borrow funds. Traded instruments fall into several standard categories (Fig. 4.2).

Cash/spot markets	Derivatives markets
• Equities • Fixed income/bonds • Currencies	• Commodity futures • Financial futures • Options • Swaps • Forwards
Other markets	
• Real estate • Art, antiques, etc.	

Fig. 4.2 Traded markets by instrument type

[3] As identified in Chap. 2, "spoofing" refers to the entry of orders to create a misleading impression of supply and demand. Spoofing orders are then cancelled before they can execute.

[4] The role of intermediaries in the provision of liquidity is discussed in more detail in Chap. 2.

While a large company may manufacture many products in various sizes, colors, and configurations, its securities are standardized into a narrow range by the type of "claim" they represent for the investor. Bond are obligations and bondholder claims are prioritized over common stockholders for instance. Financial markets draw together securities, tradable instruments, investor decision-making, and a legal and operational infrastructure to support trading and trade processing.

Markets differ depending on the timing of an asset's transfer. In derivatives markets, a transaction occurs today at a set price for an asset that the purchaser (seller) may not own (deliver) until some months or years into the future.

Market systems capture and disseminate important information for market participants. Figure 4.3 shows July 7, 2021 prices of West Texas Intermediate (WTI) crude oil traded on the New York Mercantile Exchange. A contract for 1,000 barrels of oil for August 2021 delivery last traded at $71.69 per barrel. Oil futures for "back months" (further into the future) are less expensive, a situation referred to as "backwardation." Other important information is the price change since the previous day. In this display, the August 2021 contract is trading $1.68 lower than the previous closing or settlement price of $73.37. The bid and ask quotes – 71.68 and 71.70 – show what prices buyers will pay and sellers will sell at for the indicated sizes, which in the display are shown as 35 × 207 (35 contracts can be sold at the bid and 20 bought at the ask). The trading volume (863,326 contracts) and the open, high, and low prices are also disseminated along with the time of the last update of the market data (11:20 am).

In cash or spot markets, ownership of the traded instrument is transferred directly and nearly immediately. Ordinarily, at the time a futures contract expires, its price will converge to the cash price. At the time of expiration, an owner of a contract is committed to receiving the commodity according to the contract's settlement rules that

Fig. 4.3 Energy futures market – crude oil (CL) futures

Fig. 4.4 Stock quote for Google (GOOG)

specify a date and location for its delivery. In the case of the NYMEX WTI Crude Oil futures (CL), that means a pipeline or storage facility in Cushing, Oklahoma.

As shown in Fig. 4.4, shares of GOOG can be sold for $2,597.09 (bid) and bought at $2,598.43 (ask) at the time this display was live (11:22 am). Further critical information shown to traders includes the quote sizes, where 4 × 1 means that the bid quote is good for up to four round lots (400 shares) and 100 shares are offered at the ask quote. The last trade was at $2,597.77, and Val (value) shows that shares worth $783.527 million have changed hands so far this day. The day's opening trade was at $2,606.82, and the high and low of the day so far are $2,612.80 and $2,596.03, respectively.

4.5 Foundational Technologies for Trading

Three information technologies are essential in computerizing a financial market: (1) shared data files or databases on which transaction processing systems run, (2) application software to process and respond to market data, and (3) high-capacity, low-latency network technologies. The first of these, databases or data files, allows structured sets of data to be stored in a computer and to be widely accessible in various ways.

Databases and common data files underlie the critical transaction processing systems (TPSs) that provide the capabilities for online trading and the subsequent clearing and settlement of trades. A TPS for a financial market has predefined fixed inputs and outputs such as orders and executed trades and is limited to predefined operations such as entering limit orders or market orders, cancelling a limit order, and matching a buy order and a sell order to complete a trade. A TPS follows precise order execution rules and ensures that all of the updates needed to process the transaction are completed. Consider for instance, a market sell order for 1,000 shares arrives, while the best limit order to buy is good for 1,500 shares. The technology must ensure that the 1,000 share match is recorded as a trade and that the remaining 500 shares to buy remain on the order book after the trade.

The second technology is the *applications software* used by market participants. Trading software includes price and chart displays, order management systems (OMS), and algorithmic trading software that submits orders into markets according to pre-specified rules. Market software needs to be "access restricted" so that only authenticated client users with adequate capital can place orders and trade and be connected via telecoms networks to the shared servers of the market operator. The application software a trader uses today can facilitate algorithmic trading and high-frequency trading (HFT) using market price and order book signals to enter and modify orders with minimal human intervention.

The third critical technology underpinning trading activity in financial markets is *telecommunications networks*. Today, high-speed, low-latency networks carry data from market servers to users across the globe. Market data vendors such as Bloomberg, CQG, and Reuters send market information to subscribers (who are identified at the time of logging in) and can send broadcast or targeted market messages and orders. Today, networks use packet switching protocols to move data in separate, small blocks – packets – through a series of network segments to destinations whose addresses are part of each packet. When received, packets are reassembled in the proper sequence to produce the transmitted data at the end point.

The farther the distance and the more "hops" from one network segment to the next, the longer the latency or delay from transmission to receipt. To avoid such latency, HFT traders pay for "collocation services" to place their trading computers in the same data centers that house the market's computer servers. With HFT models running on their trading computers that are typically co-located in the exchange's data center, these traders are likely to be the first movers on any orders they choose to act on, or to cancel orders they submitted, before they execute.

4.6 IT Functions in Trading

The following market functions have been the focus of computerization efforts in the financial industry:

- Information systems play an *order collection* role in the processing of trading instructions in investors' and traders' offices. With an electronic system, once an order is entered, details such as size, limit price, and time are accessible for an investor's control and measurement purposes and for transmitting to a chosen market system.
- Systems for *order routing* direct an order entered by a trader to the appropriate market. The DOT system (designated order turnaround) was introduced in 1976 for order routing on the NYSE. The system enables NYSE member firms to electronically route market orders and limit orders from their offices anywhere to the specialist post on the market floor, bypassing the floor broker's booth. By 1992, 78% of NYSE orders were arriving via DOT. At that time, the remainder arrived via phone calls to floor traders' booths.

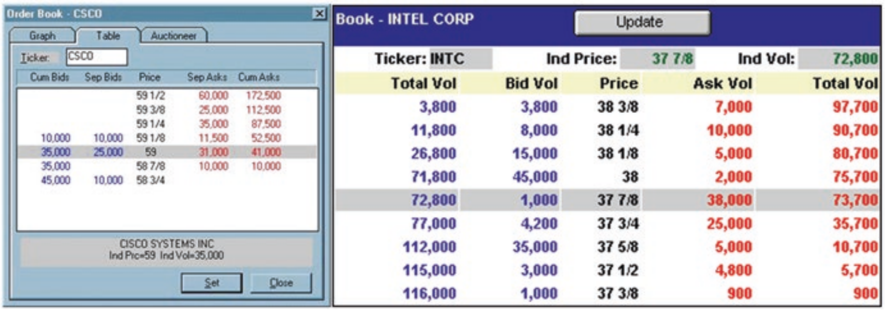

Fig. 4.5 Call auction price discovery in Cisco and Intel stock in the AZX call auction mechanism that operated from 1990 to 2001. Buyers and sellers will be matched at the shaded prices

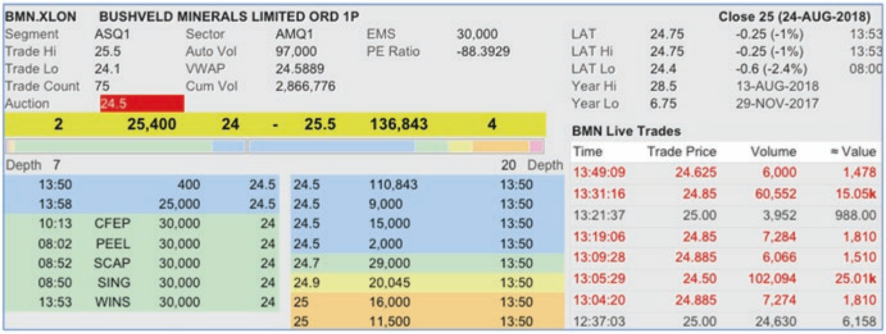

Fig. 4.6 Call auction price discovery on the London Stock Exchange. The uncrossing price will be 24.50 pence and 25,400 shares will be matched

- *Price determination* is often supported by systems that aggregate the orders submitted to a market and discover prices. The Arizona Stock Exchange (AZX) was a screen-based market for trading stocks after the daily close of New York Stock Exchange trading. The system used a single price call auction mechanism to find a price at which the maximum quantity to buy and quantity to sell can be matched. In an example from 1999 shown in Fig. 4.5, 35,000 shares of Cisco are auctioned at $59, the price that enables the greatest trade quantity to be matched. Notice that the auction is not a perfect match, as 6000 shares at $59 will remain unsold.

The London Stock Exchange (LSE) uses open, mid-day, and closing auctions to discover prices and provide added liquidity to its continuous order book system. Figure 4.6 is an example that shows a mid-day auction screen shortly before it will execute at about 14:00. The auction price is selected to be the price that enables the matching of the largest quantity of shares. In the case where there is an excess of share on one side of the market, the LSE auction executes the earliest arriving first and leaves unfilled the call auction orders that arrived later.

Order execution systems electronically match buy and sell orders in a market, and *order confirmation* systems route electronic trade verifications to the participants involved. A good example is the Reuters Dealing 2000 system launched in 1992 to electronically match buy and sell orders in the foreign exchange market. Details of executed trades are then transmitted back to the trade participants for confirmation. Today, microseconds elapse between order entry, execution, and final trade confirmation. Dealing's successor, Refinitiv, runs transactions platforms that handle an average daily volume of currency trades of nearly $500 billion in 2020.

- Systems are used for *trade reporting* and *surveillance* purposes. In the case of a fraud or market manipulation investigation, an audit trail of trades can speed investigations. The NYSE's StockWatch unit, for example, uses sophisticated software to monitor trading activities and to warn of unusual activity, which will be investigated by the staff.
- Systems *disseminate market information* more broadly. The Consolidated Tape System (CTS), introduced in 1976, imposed unified trade reporting rules and facilitated ticker publication of last sale information from any of eight US stock markets. Previously only NYSE and American Stock Exchange (AMEX) trades were reported on the ticker. Currently, the CTS informs a far broader audience of all trading activity on over 20 market venues including the NYSE, NYSE National and NYSE American, CBOE's BYX, BZX, EDGA and EDGX exchanges, Long-Term Stock Exchange, Members Exchange (MEMX), Nasdaq's BX, ISE, PHLX, and Nasdaq Stock Market.

4.7 Managing Trading Technology

A student of information systems planning to work in technology development in the financial markets industry will encounter many decisions that are no-brainers, such as upgrading software when new versions are available and changing vendors when needs change. Other decisions, such as measuring risk and setting position limits, require more thought and careful consideration, and there are strategic choices to be made with inputs from senior managers.

Speed and Reducing Latency – Nanoseconds matter for some trading strategies, but not all, depending on the investment and trading strategies being pursued by your clients. Patient trading can be beneficial and reduce costs if the holding periods of the positions are longer. Some traditional investors are concerned about the disruption and destabilization of high-frequency trading. Think of the 'flash clash' incidents (sharp price swings caused by errant trading software) that get attention when they occur. It is costly to operate a low-latency trading operation, and the optimal speed of data and order handling varies from trader to trader. Technologists need to understand how critical the timing of data transmissions is to the profitability of a strategy.

Man or Machine? – Market participants use a combination of human judgment and the rules-based logic built into customized software to manage their buy and sell orders according to their desired strategies. While market bots (robots) and algo traders capture the attention and are viewed by some as exploitive of slower human traders, the reality is more complicated. In a 2020 trial of traders accused of market manipulation, a text from one of the defendants was shared – *"As a manual trader, I can use fake bids/offers and make the algo buy/sell into my real bid/offer"* – suggesting that sometimes bot trading is less effective.[5]

A trading algorithm's effectiveness is a function of the people who developed it and the extent to which the historical data, which it was tested on, is consistent with conditions in the markets in the future. Even with their statistical sophistication, most algorithmic trading software has "kill switches" to revert to human trading judgment under extreme market conditions.

Dark or Light? – Traders typically want transparency for everyone else's orders but want to keep their own orders hidden. A disadvantage of trading in a "lit" transparent market is that simply knowing that a large order to sell (buy) is being worked through the market will put downward (upward) pressure on prices. As a result, traders in screen-based markets often choose to use hidden or "iceberg" orders or to trade in dark pools to keep their trading intentions from leaking out into the market (Fig. 4.7).

	Open "Lit" Order Book	**Hidden/Iceberg Orders**	**Dark Pool Orders**
Order placement	Enter two limit orders to sell 25,000 at $75 and $75.05	Enter a limit order to sell 50,000 at $75. Display only 10,000 in the order book with the remainder an iceberg order that will appear 10,000 shares at a time after the displayed order trades.	Enter a order to sell 50,000 into a dark pool with an indicator indicating willingness to be matched at the mid-point of the bid-ask quotes.
Possible consequences	Responding to selling pressure, the bid is cancelled, a new offer at $74.95 arrives, and the new quotes are $74.90-$74.95	The smaller displayed sell order will not trigger a price drop and buy orders arrive and fill the displayed and hidden portion of the order	A order to buy 50,000 shares or more is in the dark pool and is matched at the $75 midpoint
Possible outcome	Shares are sold for less than $75	Shares sell for $75 after some time passed and buy orders arrive	Shares sell for $75

Fig. 4.7 Example order handling approaches for a trader seeking to sell 50,000 shares of a $75 stock. The current bid and ask quotes are 74.95 and 75.05 and are good for 10,000 shares. The three illustrations shown are only possible outcomes, and any of the three approaches could turn out better or worse under different market circumstances (A major disadvantage of dark pools is their lack of participation in the price discovery process. Please see Chap. 2 (Finance) for a discussion of the advantages versus disadvantages of lit versus dark markets.)

[5] "Citadel Securities, Quantlab Loom Over Trial Probing Whether Human Traders Tricked Machines," Wall Street Journal, Sept. 18, 2020

Eliminate the Middleman? – Many observers predicted that electronic markets would squeeze out dealers and other intermediaries in the financial markets. That has not turned out to be the case, and many intermediaries operate in today's markets. Investor-driven order flow provides sufficient liquidity in only a handful of the most active stocks and financial instruments. In other markets, supplemental liquidity provision is required, and dealers and market makers step in to buy or to sell when there is an imbalance in the flow of orders. Supplemental liquidity providers tend to have short holding periods and do not try to exploit large moves over long time periods. Often referred to as "scalpers," they attempt to keep inventory and position risks low while "capturing" the bid-ask spread or taking advantage of small moves that occur frequently. Today's market-making firms, however, supply liquidity with sophisticated software and analytic risk models. They employ far fewer people than these firms did in the era of floor trading when they operated as dealers such as NYSE specialists or futures market "locals." While trading costs have come down, the market depth and the quality of price discovery remain a reason trading intermediation remains desirable.

Fragmented Markets – Technology has driven a proliferation of markets and competing venues for trading. In 2020, the United States had 16 licensed equity exchanges, up from 11 in 2014, including the NYSE, Nasdaq, CBOE, and IEX, and about 50 alternative trading systems (ATSs). ATSs, which include dark pools, accounted for 40% of trading in 2019 according to Rosenblatt Securities. Off-exchange trading also goes through "wholesalers" or market makers, such as Citadel Securities and Virtu Financial, which execute retail orders for brokerage firms with the promise of providing better trading prices. While market makers may end up executing some trades on an exchange or in a dark pool, they often wind up 'internalizing' (e.g., buying for their own account when a customer sells) a large portion of the orders by taking on position risk and using their capital to complete them. The evidence suggests this competition is good for market participants, but with multiple trading venues, there are also concerns that *fragmentation* can impair price discovery and reduce liquidity and also make liquidity more difficult to access. One counterargument is that with sufficient transparency and shared market information, multiple technology-connected trading venues may effectively provide the benefits of a single, consolidated market, but the jury is still out on this one.

Computerized Trading Messaging Standards and FIX – As computerized order routing and trading began to replace phone calls and paper trading tickets in the 1980s, technologists had to work with different vendor-specific electronic communications formats and proprietary messaging standards. The NYSE, for instance, used its own message formats in its Common Message Switch (CMS) that connected traders away from the trading floor to its DOT system. The separate and incompatible interfaces for different exchanges and different brokerage firms created a need to consolidate traders' points of entry and to realize cost savings by standardizing on a single, open protocol for trade messages that was not controlled by a vendor or an exchange.

In 1992, the Financial Information eXchange (FIX) was founded as a result of a collaboration between IT teams at a "sell-side" firm (Salomon Brothers) and a "buy-side" firm (Fidelity Investments). FIX is a series of specifications for

Message:	8=FIX.4.4|9=122|35=D|34=215|49=CLIENT12|52=20100225-19:41:57.316|56=B|1=Marcel|11=13346|21=1|40=2|44=5|54=1|59=0|60=20100225-19:39:52.020|10=072|		
Tag	**Field**	**Value**	**Description**
8	BeginString	FIX.4.4	Identifies beginning of new message and protocol version
9	BodyLength	122	Message length, in bytes
35	MsgType	D	NewOrderSingle
34	MsgSeqNum	215	Integer message sequence number
49	SenderCompID	CLIENT12	Identifies firm sending message
52	SendingTime	20100225-19:41:57.316	Time of message transmission
56	TargetCompID	BrokerA	Identifies receiving firm
1	Account	Marcel	Account mnemonic
11	ClOrdID	13346	Unique identifier for Order
21	HandlInst	1	Instructions for order handling: 1 = Automated execution order, private, no Broker intervention.
40	OrdType	2	Order type. 2 = Limit
44	Price	5	Price per unit of quantity (e.g. per share)
54	Side	1	Side of order. 1 = Buy
59	TimeInForce	0	Specifies how long the order remains in effect. 0 = Day
60	TransactTime	20100225-19:39:52.020	Time of execution/order creation
10	CheckSum	72	Three bytes, simple checksum

Fig. 4.8 Sample a FIX message for a limit order to buy at 5 sent by CLIENT12 to Broker A and a table describing each of the field in the tagged-field message. (From: http://www.validfix.com/fix-analyzer.html)

machine-readable messages related to securities transactions and markets and their real-time transmission among market participants. For an IT professional, managing trading applications and keeping latency low increasingly require an understanding of the FIX protocol.

A FIX message is a digital message with a list of fields with numerical tags and values separated by "|." Each tag corresponds to a different field for which a certain set of user-entered values is allowed. An example of a FIX message is presented in Fig. 4.8.

The pattern in each FIX message is Tag=Value|Tag=Value|Tag=Value|…. Depending on the purpose of each message, different sets of tags and permitted values are included. By using FIX technology in their trading applications, market participants are effectively agreeing to speak the same "language" with the markets, the exchanges that they use, and the broker-dealer counterparties that serve them.

Further Information Technology Issues – Technology and the use of the trading applications that rely on common standards such as SWIFT and FIX have made traders more productive and have reduced errors that occurred in manual trading. Nonetheless, advances and new applications of IT open complex questions for market regulators and trading organizations that are described below.

Transparency – The amount of information available from markets and the emergence of direct access to the trading process have empowered investors to manage their trading activities more closely. Pre-trade data exchanged in some markets include the identity of the firm that placed the order. However, some participants prefer anonymity to prevent their proprietary activities from being front-run or being "reverse-engineered" by other participants. Even innocuous post-trade information such as the identities of the executing broker and the clearing firms can signal what an investor or hedge fund is doing (such as building up a large position in advance of a takeover offer).

Information Disclosure – There are many types of regularly scheduled public information releases from companies, including their annual financial statements and quarterly reports. Private and insider information is more concerning since trading on privileged information can be illegal and disadvantages uninformed traders and erodes confidence in market integrity. Greater sharing and analysis of qualitative, unstructured information – such as the text of a speech or a letter to shareholders – provides heightened visibility into company activities, and this could level the playing field and reduce information asymmetries potentially harming less sophisticated investors. Hedge funds not surprisingly are at the leading edge and have developed proprietary text mining techniques to rapidly assess the positive or negative "sentiment" of speeches, news stories, or company press releases.

Complexity – As markets have innovated and competition among trading venues for order flow has grown, new complexities and challenges are emerging. In the past, the fees charged to broker-dealer firms for their trade executions were fairly uniform across stock exchanges. A new range of rebate approaches and fee models have developed to attract order flow. The use of incentives for certain order types was pioneered by the Island ECN in the late 1990s. In its maker/taker model, Island attracted limit order users by rebating $0.002 per share if their order traded and charging the market order a $0.003 per share fee. Island kept the difference. Recently, some trading venues have inverted this model to charge the limit order trader and rebate the "taker." Such incentives can lead to orders being routed *not* based on where the best price discovery and liquidity are, but on where the firm will maximize its payment for order flow. The results could be pricing distortions and publicly visible bid/offer prices in the market that are less accurate since rebates and other discounts are hidden.

System Reliability – Like other technologies, trading systems are subject to failures, breakdowns, and unanticipated responses to conditions. In 2012, a prominent market-making firm, Knight Capital, caused a major stock market disruption and suffered a $440 million trading loss. A significant error in the operation of its automated routing software for equity orders caused it, in roughly 45 minutes, to route millions of orders into the market that resulted in over 4 million trades in 154 stocks for nearly 400 million shares. For instance, the flood of orders to buy shares of Wizzard Software Corporation caused its price to move from $3.50 to $14.76. The SEC's erroneous trade rules[6] developed after the 2010 "flash crash" led to trades at least 30% away from the "reference price" being cancelled, which happened for Wizzard and five other stocks.

Knight was found to have violated SEC rules that required broker-dealers to have controls and procedures to limit the risks associated with automated trading systems and to prevent these types of errors. Mary Schapiro, the then-Securities and Exchange Commission (SEC) chairperson, recommended the voluntary guidelines – known as Automation Review Policies that have covered technological systems since the 1987

[6] See FINRA Rule 11890-Clearly Erroneous Transactions. https://www.finra.org/rules-guidance/rulebooks

crash – become mandatory: "As the SEC catches up with the realities of today's market, it seems an appropriate moment to require that every entity in an interconnected system work to ensure its capacity, resiliency, and security."

A further example occurred on Thursday, October 1, 2020, when the Tokyo Stock Exchange experienced a full day shutdown of its market when a data device malfunctioned and the switchover to the backup device failed. Testing and backup plans are crucial because of the numerous interconnections and interdependencies and because changes to components or software in one "layer" of the stack can trigger unanticipated breakdowns elsewhere.

Open Architecture and Scalability – Market systems are designed today with open architectures that make adding or upgrading components efficient. Non-proprietary approaches are more cost-effective and provide a high degree of scalability. An added benefit is not being tied into a single vendor. Today's trading platforms are built on open source software and can be deployed in many different data center and cloud environments.

4.8 Conclusion

The technology of trading has evolved rapidly, and market quality in many respects has been improved. Traders are more productive than ever, with computer algorithms handling the work of entering orders while monitoring and responding to market conditions, and trading professionals able to focus on more complex orders and formulate new strategies. A senior trader at Instinet made the following comment:

> No question, the markets are better now than ever before. Everybody agrees with that. Spreads are tighter; more volume can go through the pipes, all the exchanges compete. Indeed, there are many ways to execute a stock, and there are dark pools, and exchanges. That said, it's complicated
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> - Anthony Fortunato, Chapter 2 in "Technology's Challenge to Regulators: *40 Years of Experience with the National Market System (NMS): Who Are the Winners and What Have We Learned?*" Schwartz, R., J. Byrne, and E. Stempel, eds., Springer, forthcoming, 2021

In spite of the complexity, the following facets of IT are of fundamental importance in trading environments:

System Reliability – Shutdowns of financial trading make front page news and often lead to political interventions. Surging trading volumes in the late 1960s led to a paperwork crisis in US stock markets as a backlog of unsettled trades built up. To address the problem, US equity markets were closed on Wednesdays from mid-1968 to early 1969. In response, both the US Senate and House held hearings on the matter and, in consultation with the SEC, drafted legislation to deal with the paperwork crisis. In 1972 and 1973, the National Securities Clearing Corp. and Depository Trust Company were established to provide computerized, "book-entry" transfer of ownership and to reduce the movement of paper securities certificates. But the reliability of the trading systems themselves is of tremendous importance.

Open Architecture – Non-proprietary technology and vendor-neutral standards are preferred in financial markets. Open architectures enable innovations by market participants and foster competition among technology vendors to improve components in each layer of the "stack."

Scalability – Trading volumes fluctuate widely in equity markets. Peak trading volumes can be 100 times larger than average volumes, and a news announcement about a company or an update from the Federal Reserve chair can lead to a spike in trading. Market capacity needs to be able to scale up rapidly in order to handle the occasional bursts of heavy market activity without disruption or significantly increasing latency. In addition, an exchange must be able to handle an order flow that, over time, continues an upward trending.

In this chapter, we have focused on the critical skills and the necessary understanding of technology applications in financial markets. The foundational components of IT systems were presented along with issues of market regulation and risk management. We identified how IT streamlines and reduces costs for existing institutions but also provides a platform for innovators and start-ups seeking to compete and disrupt powerful incumbent organizations. This background is intended to help you to become a confident technologist who can analyze data and make decisions regarding how to react to today's financial market trends.

Financial markets have long histories, but the economic forces underlying markets are little changed from the 1700s when the precursors of the London Stock Exchange and the New York Stock Exchange were established at Jonathan's Coffee House (1761) and under a buttonwood tree (1792). Although IT is well-known as a transformational force in markets, research and teaching in the academic fields of IS and Finance are just beginning to adequately describe the optimal strategies for deploying IT in financial markets to reduce trading costs and improve liquidity. Consequently, this chapter has identified the major transformational impacts that IT has had and presented a foundation for understanding the strategic technologies essential for managing financial firms and competing successfully in today's capital markets.