Advanced Python for Finance

Lecture 3

Lecture 3

Transaction Cost Analysis

Execution Strategy Types

- Volume Participation
- Time Weighted Average Price
- Volume Weighted Average Price
- Event Driven Strategies
- Order Routing
- Case Study: Developing a First Execution Algorithm

Fundamentals of Transaction Costs

Transaction Costs

In part I of this lecture we will present a fundamental overview of transaction costs involved in financial securities trading and portfolio management.

- We will present a classification system for various costs with respect to the nature (fixed or variable) and visibility (visible or non-transparent) of those costs.

- We will also review Perold's *implementation shortfall* as an objective measure of total transaction cost involved in portfolio transactions.

Overview

The implementation of a financial decision is *not* free.

- It has an associated cost and usually results in *reduced* portfolio returns.
- If managers do not properly manage these costs during all phases of the investment cycle (depicted in Figure 1) many of the fund's superior investments will become only moderately profitable and other higher-quality investments will become unprofitable.
- As a result traders and investment managers need to be more proactive in *managing* transaction costs in order to achieve their benchmark and provide investors with competitive portfolio returns.

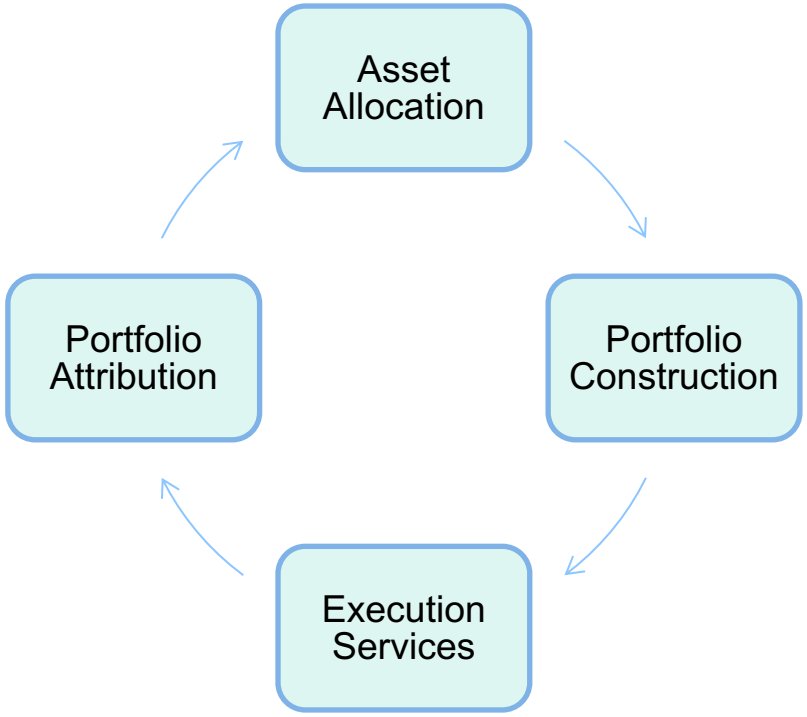


Figure 1: Phases of the Investment Cycle

The Transaction Cost Pyramid

Figure 2 shows the pyramid of costs associated with investment and portfolio management (as briefly discussed in an earlier lecture). Each of these costs adversely impact returns in different ways and by various degrees.

- The cost components *most* visible from a distance contribute the *least* to the total transaction cost.
- Costs *least* visible (non-transparent) from a distance contribute *most* to the total transaction costs.

Fortunately, these *non-transparent* cost components provide the greatest *opportunity* for cost reduction.

- A skilled trader or investment manager can add value to the investment cycle and reduce portfolio slippage by effectively managing these costs.
- Unfortunately, however, it is *not* possible to reduce all cost simultaneously.
- Careful transaction cost management is required to *balance* the impact of various costs.

Figure 2. The Transaction Cost Pyramid

The Nature of Transaction Costs

- Transaction costs are costs associated with implementing business decisions that are *incremental* to the cost of goods or services purchased or sold.
- In economic terms, transaction costs refer to costs paid by buyers and not received by sellers and/or paid by sellers but not received by buyers.
- Transaction costs consist of both **fixed** and **variable** costs, and **transparent** (visible) and **non-transparent** (hidden) costs.
  - **Fixed** components are those costs that are *independent* of the actual implementation strategy.
  - **Variable** costs are those costs that depend on the implementation strategy, and thus can be controlled and reduced during implementation.
  - **Transparent** (visible) costs refer to the costs whose structure is *known* in advance (such as commission fee or tax rate).
  - **Non-transparent** (non-visible) costs are those costs whose amount or structure is *not known* in advance (such as market impact); thus, structures must be inferred or estimated from market observations.
- Generally, it is the **variable non-transparent** costs that account for the largest percentage of transaction costs.

Transaction Cost Classification System

Transaction costs can be classified into *three* broad categories: *investment related*, *trading related*, and *opportunity cost related*, as shown in Figure 3.

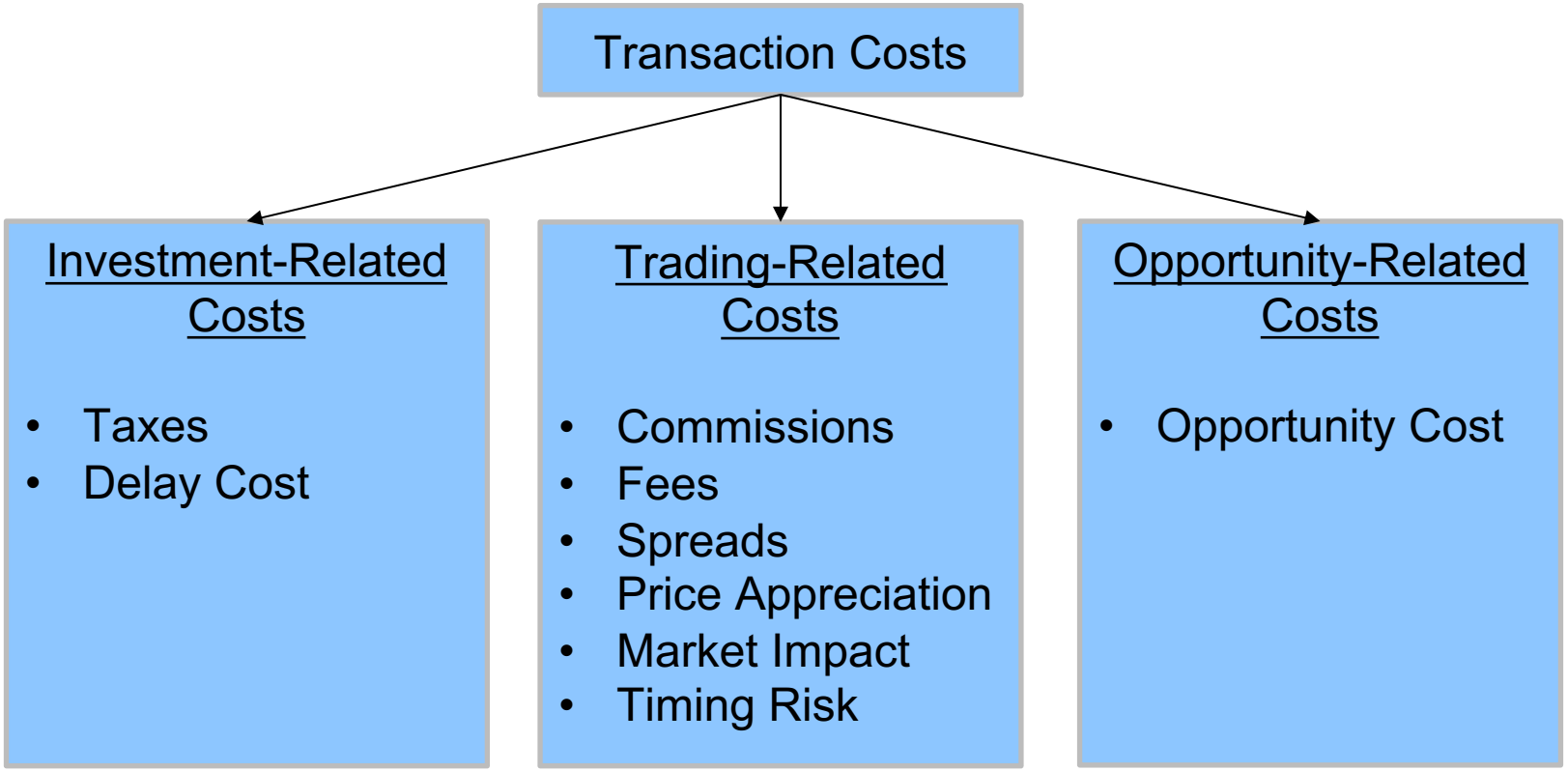


Figure 3: Transaction Cost Classification

Investment Related Costs

Investment-related transaction costs include manageable costs during the *investment decision* phase of the investment cycle and include taxes and delay cost.

Taxes

- Although taxes generally depend on specific portfolio transactions (e.g. capital gains tax), and is hence a variable cost component, since tax rates are in most cases known in advance, taxes generally form a visible transaction cost component.
- Treatment of taxes is generally complicated and best if incorporated in the investment decision process from the beginning.

Delay Cost

- On the other hand, delay cost is a *non-transparent variable* transaction cost component generally associated with indecisiveness or waiting to trade.
- This cost can arise due to lack of proper communication between investment managers and traders in specifying *implementation goals* of investment decisions.
- The longer it takes for traders and managers to resolve proper implementation objectives (often exacerbated by the lack of proper analytical tools), the more potential there is for price movement making investment decisions more costly.

Trading Related Costs

- Trading-related transaction cost components comprise the largest subset of transaction costs. These costs include those that arise during *implementation phase* of investment decisions and can be effectively managed during proper execution of the list.
- While these costs cannot be eliminated, they can be dramatically *reduced* via a trading strategy that best meets the objectives of the fund.
- These costs consist of both **fixed** and **variable** costs and **transparent** (visible) and **non-transparent** (non-visible) costs.
  - The associated trading-related costs of *commission*, *fees*, and *spread*, can be further categorized as transparent *trading service* cost components associated with working with brokers, locating liquidity, negotiating prices, and clearing and settlement.
  - Non-transparent variable cost components consist of *price appreciation*, *market impact*, and *timing risk*.
- Traders can affect cost and risk of implementation through selection of trading strategies.
  - For instance, price appreciation and timing risk are *minimized* via implementation with an *aggressive* trading strategy.
  - Market impact, however, is *increased* with an aggressive strategy and lowest with a passive strategy.
  - This implies that traders need to *balance* trade-off between these cost components.
  - Trading costs are generally dependent upon the *trade list*, *order size* and *liquidity*, *volatility*, and other market conditions (e.g. volume correlation across all names in the list), and specified implementation strategy.

Opportunity Cost

Opportunity cost represents the *foregone* profit of *not* being able to fully implement an investment decision.

- Opportunity cost exists because insufficient market liquidity prevents completion of the order or the price moves outside a specified range.
- It combines the price change over the trading horizon and number of unexecuted (residual) shares.
- Opportunity cost can arise because traders are unable or unwilling to transact at existing market prices, or because of insufficient market liquidity.
- It can also arise because investment managers specify orders that are too large to be absorbed without producing adverse price movements.

One way to reduce opportunity costs is proper *pre-trade* analysis and *cost estimation* of the trade list.

- If managers determine that the market cannot readily absorb the desired quantity of shares, managers can *modify* the order to one that can be easily absorbed by the market and then invest surplus funds in the next most attractive investment vehicle.
- The net result is decreased opportunity cost and increased portfolio returns.

Transaction Cost Formulation

We can use the this classification scheme to formulate a definition of transaction cost:

$$TC = \underbrace{\left\langle \begin{matrix} Taxes \\ Delay\ Cost \end{matrix} \right\rangle}_{\text{Investment Related}} + \underbrace{\left\langle \begin{matrix} Commisions \\ Fees \\ Spreads \\ Price\ Appreciation \\ Market\ Impact \\ Timing\ Risk \end{matrix} \right\rangle}_{\text{Trading Related}} + \underbrace{\langle Opportunity\ Cost \rangle}_{\text{Opportunity Related}} \qquad \text{(EQ 1)}$$

Transaction Cost Formulation

If we incorporate the concept of visibility, an alternative cost categorization would be the following (equivalent) formulation of transaction costs:

$$TC = \underbrace{\langle Delay\ Cost \rangle}_{\text{Investment Related}} + \underbrace{\left\langle \begin{matrix} Price\ Appreciation \\ Market\ Impact \\ Market\ Timing \end{matrix} \right\rangle}_{\text{Trading Related}} + \underbrace{\langle Opportunity\ Cost \rangle}_{\text{Opportunity Related}} + \underbrace{\left\langle \begin{matrix} Taxes \\ Commisions \\ Fees \\ Spreads \end{matrix} \right\rangle}_{\text{Visible/Transparent Costs}}$$

Non-transparent Costs

(EQ 2)

This latter formulation provides the basis for our transaction cost measurement and transaction cost estimate framework described below.

Cost Measurement

The measurement of transaction costs can be written in the form of Perold's *implementation shortfall* measure, where we distinguish these non-transparent costs as investment, trading and opportunity cost as follows:

$$TC = \underbrace{\underbrace{X(P_d - P_0)}_{\text{Investment–related}} + \underbrace{\sum x_j (P_j - P_0)}_{\text{Trading–related}} + \underbrace{\left(X - \sum x_j\right)(P_n - P_0)}_{\text{Opportunity cost}}}_{\text{Non–transparent Cost Component}} + Visible$$

(EQ 3)

Cost Measurement

$$TC = \underbrace{X(P_d - P_0)}_{\text{Investment–related}} + \underbrace{\sum x_j (P_j - P_0)}_{\text{Trading–related}} + \underbrace{\left(X - \sum x_j\right)(P_n - P_0)}_{\text{Opportunity cost}} + Visible$$

$$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}_{\text{Non–transparent Cost Component}}$$

where

X = total number of shares, $X > 0$ indicates a buy, and $X < 0$ indicates a sell

x_j = number of shares executed in j-th trade

$\sum x_j$ = total number of shares executed

$X - \sum x_j$ = number of unexecuted shares

P_d = manager's decision price

P_0 = stock price when order was released to market

P_j = price of j-th trade

P_n = stock price at end of trading

Visible = visible costs of commission, fees, taxes and spreads

Cost Measurement

$$TC = \underbrace{\underbrace{X(P_d - P_0)}_{\text{Investment-related}} + \underbrace{\sum x_j (P_j - P_0)}_{\text{Trading-related}} + \underbrace{\left(X - \sum x_j\right)(P_n - P_0)}_{\text{Opportunity cost}}}_{\text{Non-transparent Cost Component}} + Visible$$

Usually prices for P_d, P_0, P_n and are taken as the *midpoint* of the bid-ask spread at the corresponding time. Therefore, spread cost is *included* in the trading related component. The price of the trade P_j, however, is taken at its *exact* transaction price. The cost specification given above distinguishes those non-transparent transaction cost components from visible cost components. This classification scheme is essential for understanding transaction costs and developing estimation methodologies.

Discussion: Investment Costs

The *investment-related cost* classification is measured as the *change* in the value of the portfolio *between* the time managers make the investment *decision* and the time traders are prepared to *trade*. This is computed simply as the number of shares in the order multiplied by the price change, that is, $X(P_d - P_0)$. In the majority of situations, managers purchase stocks that are rising, and sell stocks that are falling. Thus, the associated *delay* reflects a *cost* to the fund. This component constitutes a *substantial* cost and their estimates show the cost to be in the order of 30–50 bp per transaction.

However, as traders practice proper transaction cost management, the time between the decision time t_d and order release time t_0 becomes small causing the *delay cost* to become effectively zero, that is,

$$P_d - P_0 \to 0 \quad as \quad t_d - t_0 \to 0 \qquad \text{(EQ 4)}$$

$$TC = \underbrace{X(P_d - P_0)}_{\text{Investment-related}} + \underbrace{\underbrace{\sum x_j (P_j - P_0)}_{\text{Trading-related}} + \underbrace{\left(X - \sum x_j\right)(P_n - P_0)}_{\text{Opportunity cost}}}_{\text{Non-transparent Cost Component}} + Visible$$

Discussion: Trading Costs

The *trading-related cost* classification φ is measured as the difference between the total transaction dollars and the value of that number of shares evaluated at the price of order release P_0, that is:

$$\varphi = \sum x_j \left(P_j - P_0\right) \qquad \text{(EQ 5)}$$

Since the price of order release P_0 is evaluated at the midpoint between the bid and the ask, the *spread cost* is already *included* in the trading cost calculations and does not need to be incorporated as its own separate component. The trading-related cost comprises the greatest portion of transaction cost but can be effectively *reduced* if proper transaction cost management techniques are put into effect.

$$TC = \underbrace{X\left(P_d - P_0\right)}_{\text{Investment–related}} + \underbrace{\sum x_j \left(P_j - P_0\right)}_{\text{Trading–related}} + \underbrace{\left(X - \sum x_j\right)\left(P_n - P_0\right)}_{\text{Opportunity cost}} + Visible$$

$$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}_{\text{Non–transparent Cost Component}}$$

Discussion: Opportunity Cost

The *opportunity cost* classification represents the missed profiting opportunity that results from *not* being able to completely implement investment decisions. It is measured as the number of *unexecuted shares* multiplied by the price change between the time of order release P_0 and the price at the end of trading P_n. This measure is intended to represent the change in portfolio value that is not enjoyed by funds. The cost of unexecuted shares over the *entire* implementation horizon t_d to t_n can be decomposed as:

$$OC = \left(X - \sum x_j\right)\left(P_n - P_d\right) = \underbrace{\left(X - \sum x_j\right)\left(P_d - P_0\right)}_{\text{Investment–related}} - \underbrace{\left(X - \sum x_j\right)\left(P_n - P_0\right)}_{\text{Trading–related}} \quad \text{(EQ 6)}$$

Thus, managers identify opportunity cost as both investment related and trading related. Since managers typically buy stocks that are rising and sell stocks that are falling (as well as exert an imbalance in the market supply demand equilibrium of the stock causing adverse price movement), this component generally reflects a *cost* to investors.

$$TC = \underbrace{\underbrace{X\left(P_d - P_0\right)}_{\text{Investment–related}} + \underbrace{\sum x_j\left(P_j - P_0\right)}_{\text{Trading–related}} + \underbrace{\left(X - \sum x_j\right)\left(P_n - P_0\right)}_{\text{Opportunity cost}}}_{\text{Non–transparent Cost Component}} + Visible$$

Discussion: Opportunity Costs, cont'd.

It is quite possible to effectively *reduce* opportunity cost to *zero* through proper transaction cost management techniques; there the gap between investment decisions and order release should ultimately be *minimal*. Trading-related opportunity cost exists because of inadequate *liquidity conditions* and/or substantial *adverse price movement*. But if managers and traders work together they could *assess* liquidity conditions and estimate execution costs to determine the appropriate *order size* that can be readily absorbed by the market. Within managers' specified price range the number of unexecuted shares will effectively fall to zero. Thus,

$$OC \to 0 \quad as \quad X - \sum x_j \to 0 \qquad \text{(EQ 7)}$$

The *visible cost* classification consists of commissions, spreads, taxes, and any other fee charged to investors (e.g., ticket charge, clearing and settlement fee). Many times, however, brokers *bundle* these fixed costs (visible *excluding* spreads and taxes) into the *commission rate* charged by the broker and investors never see the costs. For the most part, these visible costs represent the *smallest* portion of the total transaction cost and *cannot* be affected or controlled by proper transaction cost management practices (i.e., selection of implementation strategy).

$$TC = \underbrace{\underbrace{X(P_d - P_0)}_{\text{Investment-related}} + \underbrace{\sum x_j (P_j - P_0)}_{\text{Trading-related}} + \underbrace{\left(X - \sum x_j\right)(P_n - P_0)}_{\text{Opportunity cost}}}_{\text{Non-transparent Cost Component}} + Visible$$

Basics of Cost Estimation

Our discussion of the proper analytical framework for estimating transaction costs and developing and evaluating appropriate trading strategies focuses on the *non-transparent*, *variable*, *trading-related* transaction costs since these are the costs that can be *controlled* during implementation. Subsequently, these pre-trade transaction costs will be appropriately referred to as trading costs. In short, the pre-trade costs are estimated based on the following price trajectory formulation:

$$p_t = p_{t-1} + \mu_t + \kappa_t + \varepsilon_t \qquad \text{(EQ 8)}$$

where,

p_t = price of the t-th trade

μ_t = natural price appreciation from time t-1 to t

κ_t = market impact of the t-th trade

ε_t = white-noise price innovation

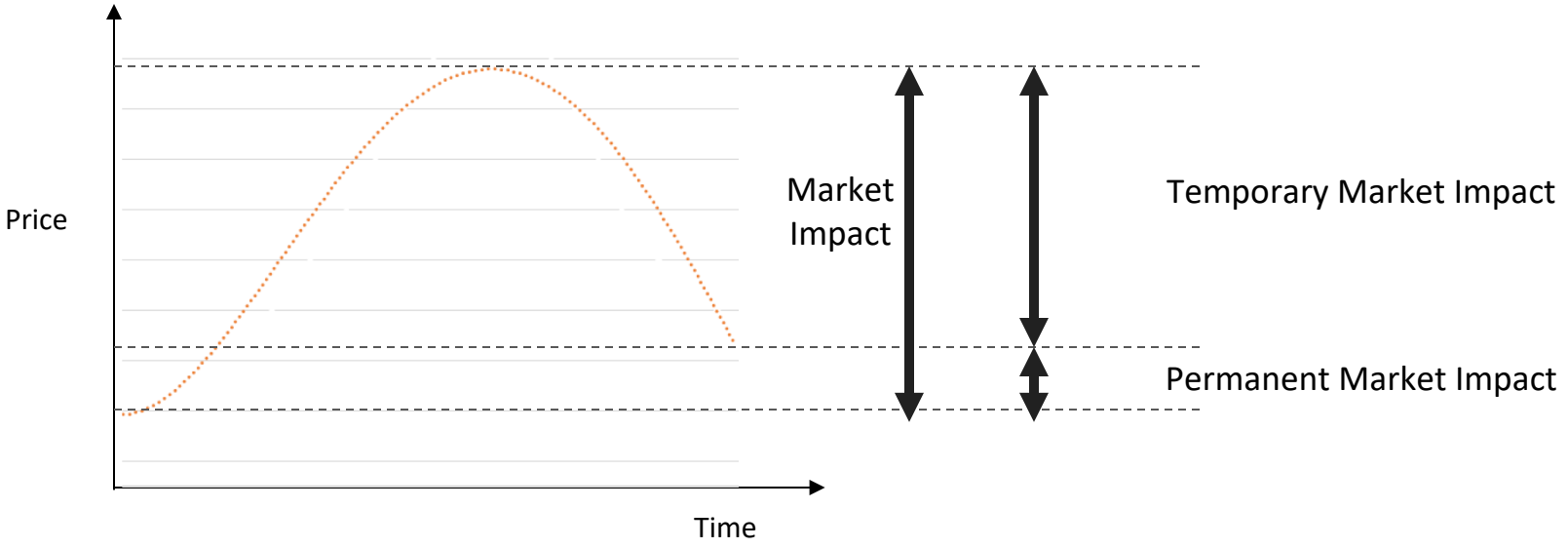
Market Impact

Market impact is perhaps the most significant topic in transaction cost analysis.

It represents the price change caused by the execution of a specific order, and typically has an adverse effect on price, driving prices up (buy) or down (sell). There are two main driving factors for market impact:

- Temporary Impact: Caused by 'consumption' of liquidity (orders) by 'walking ' the order book
- Permanent Impact: Caused by information conveyed to the market through the execution of order in the market

Market Impact = Temporary Impact + Permanent Impact



Key Points in the Transaction Lifecycle

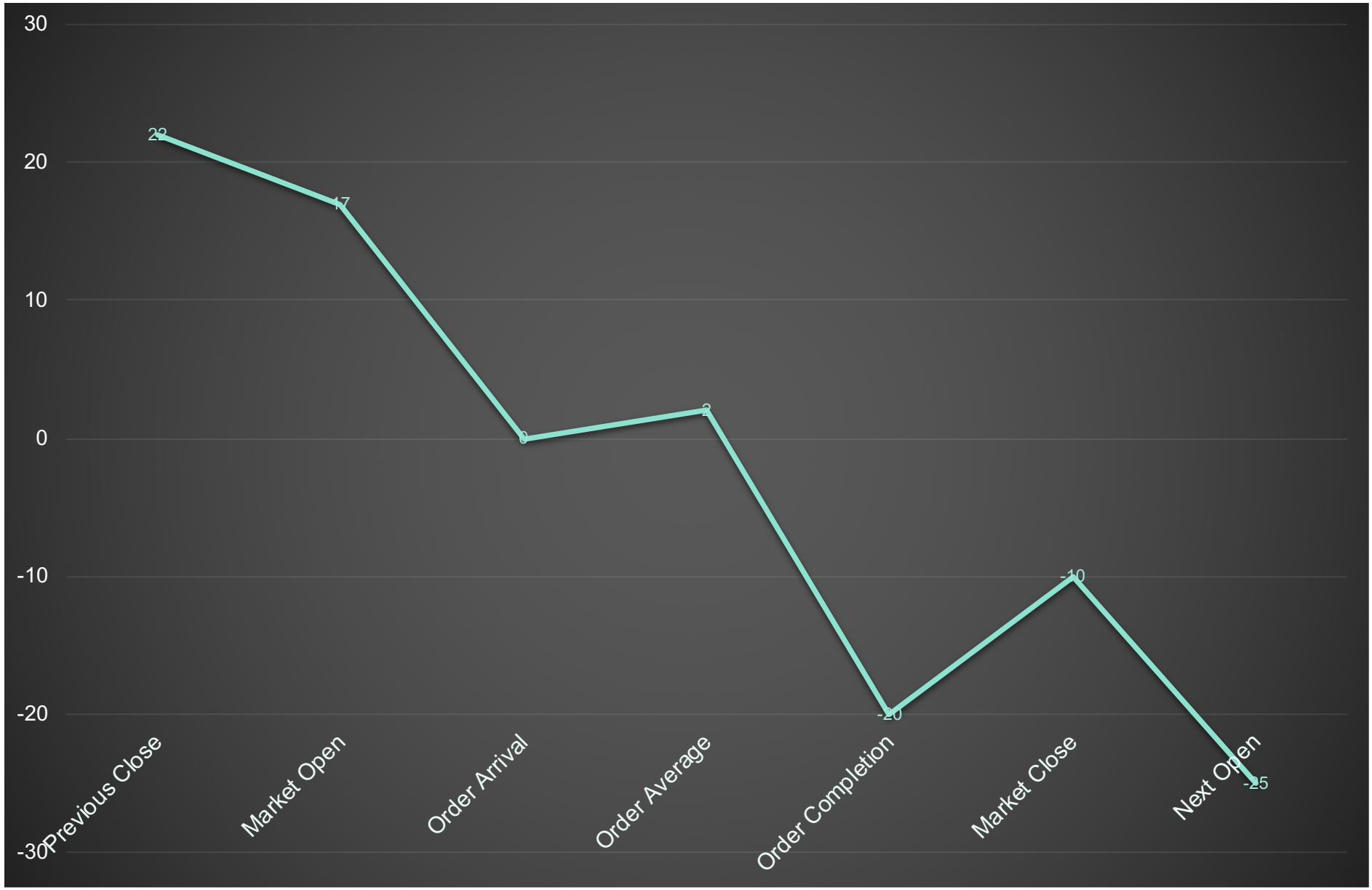
Lifecycle Point	Definition
Previous Close	Last price of previous trading session
Market Open	Exit price of opening auction
Order Arrival	Price at the time an order (or the desire to trade) arrives. One of: • Last price (if instrument is open and liquid market) • Market midpoint (if instrument is not open or not sufficiently liquid) • Previous close (if instrument is not open and/or current market is insufficiently developed (e.g. no bid or offer or excessively wide spread)
Average Price	Volume-weighted average execution price
Order Completion	Last price at time of order completion
Market Close	Exit price of closing auction
Next Open	Exit price of next trading session's opening auction

Common Performance Benchmarks

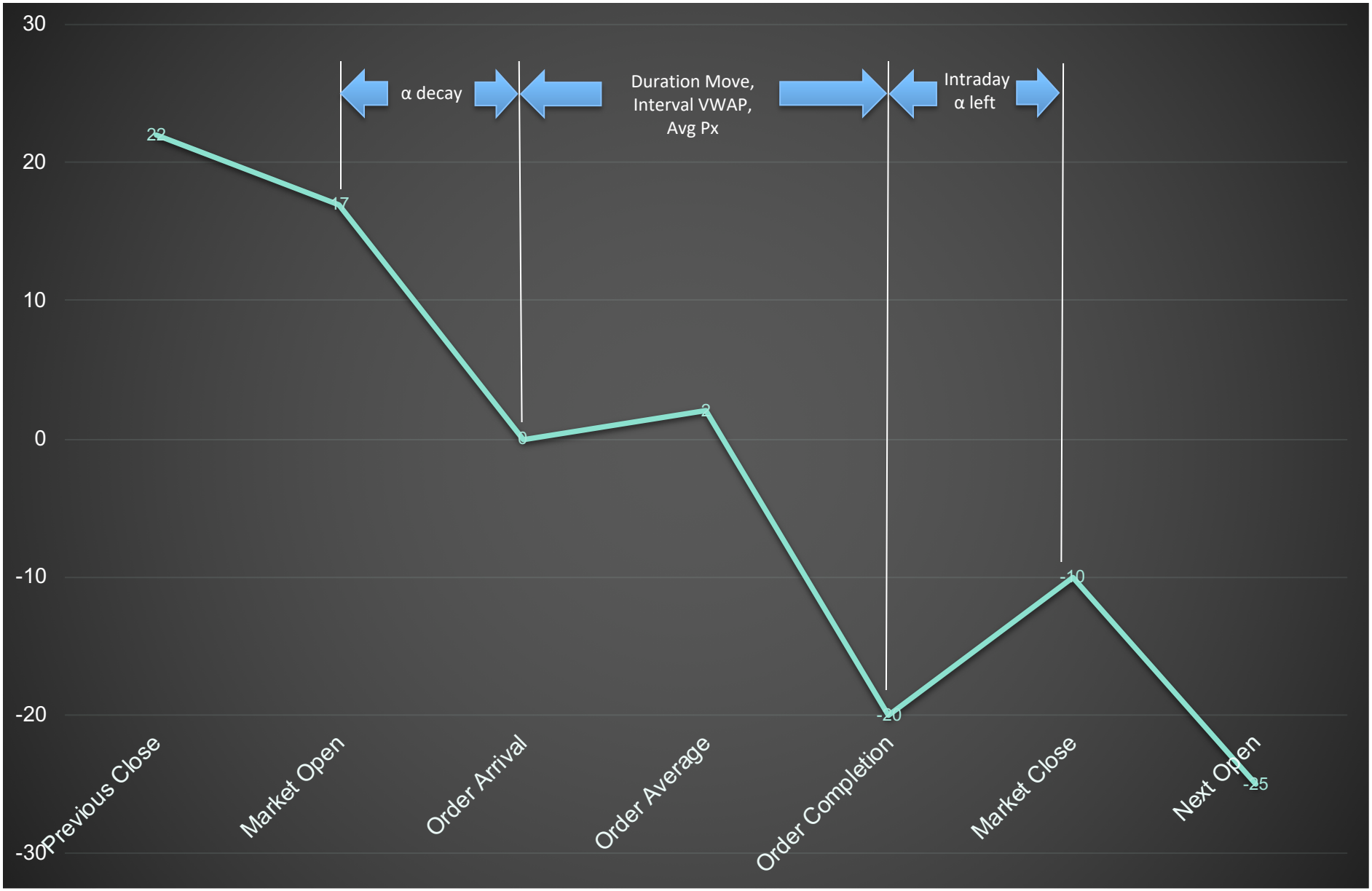
Metrics and Benchmarks	Definition
P_{avg} Volume weighted average price of *order*	Given an order of quantity Q, with executions of quantity q at price p, : $$\frac{\sum(q_i \times p_i)}{Q}$$
TWAP Time-weighted *market* average	1. For each bin i, mean($open_i$, $high_i$, low_i, $close_i$) 2. Calculate the mean across all bins
VWAP (or $VWAP_{mkt}$) Volume-weighted *market* average	$$= \frac{\sum(qty_{@price} \times price)}{total\ market\ qty}$$
Performance vs. TWAP	= $P_{TWAP} - P_{avg}$ *
Performance vs. VWAP	= $P_{VWAP} - P_{avg}$ *
Performance vs. Arrival/IS	= $P_{arrival} - P_{avg}$ *
Performance vs. Open	= P_{OPEN} - P_{avg} *
Performance vs. Close	= $P_{CLOSE} - P_{avg}$ *

**In practice these are standardized, e.g.: (($P_{TWAP} - P_{avg}$) / P_{avg}) * 10000 and expressed in basis points*

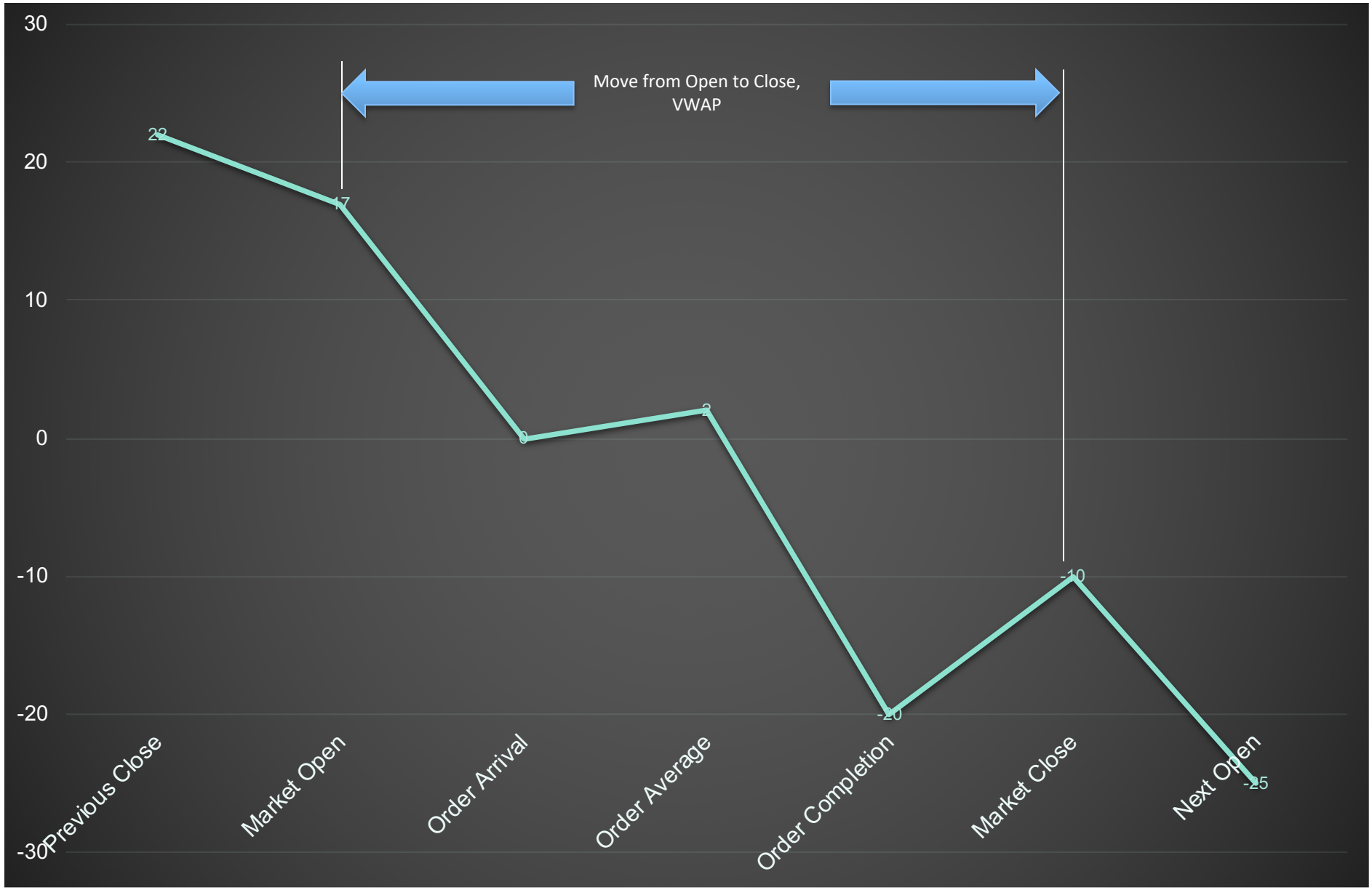
Performance vs. Points in Time



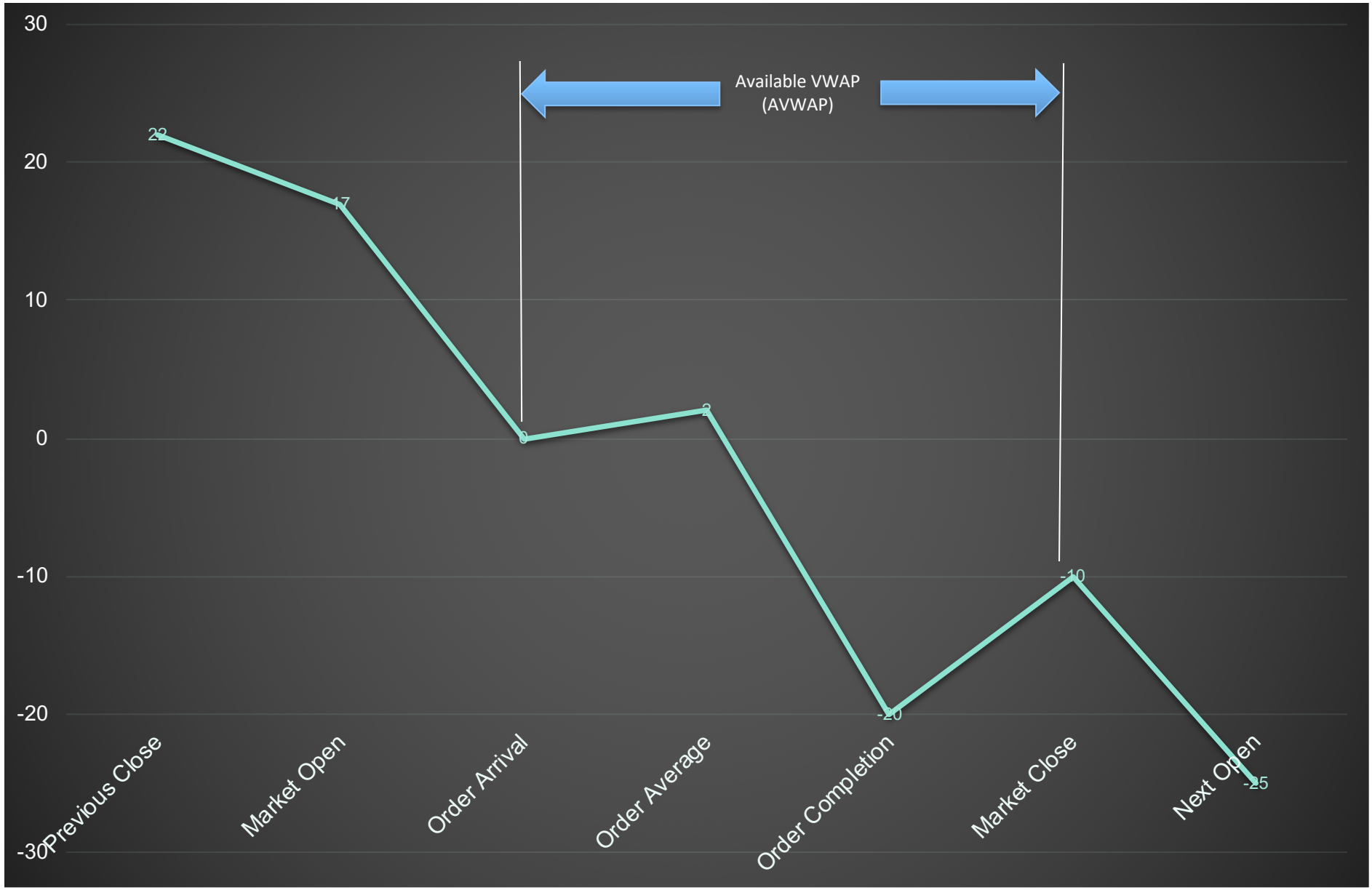
Order Life Span



Intraday Move, VWAP



Available VWAP



Post-Trade TCA – Examples

Post-Trade Analyses focus on <u>average performance of multiple trades</u> over time:

- By Algo (if applicable)
- By Benchmark
- By Trader
- By Duration
- By Sector
- Etc.

Single Stock TCA

- Outlier analysis (i.e. what went wrong!)
- Not as common for general trades

Trading Summary

Value Traded:	€3,053,204,896
(Bought):	€1,513,902,868
(Sold):	€1,539,302,028
Number Of Orders:	8,204
(Fills):	162,334
Average Order Size:	€372,160.52
(Average Fill Size):	€18,808.17
Book Spread (depth):	31.18 BPS
Book Spread (touch):	20.70 BPS
Average Duration:	0h 50m
Distinct Instruments:	519

Execution Style:

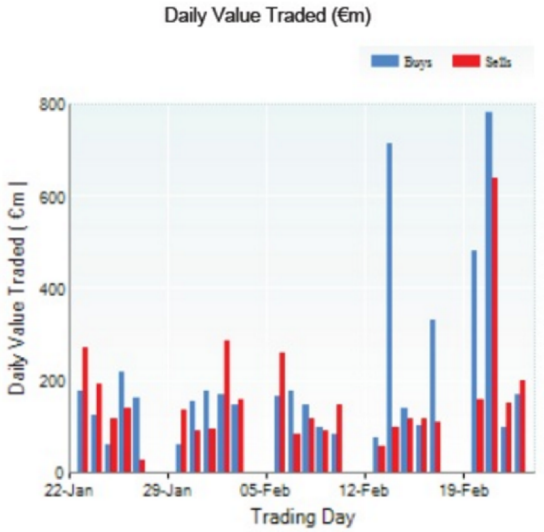
Aggr	Pass	Mid
99.3%	0.7%	0.1%

Venue Types:

Prim	MTF	Other
94.3%	0.0%	5.7%

Venues Traded:

XMAD: 71.51% XPAR: 7.02% XETR: 5.53% XHKG: 2.81% XNYS: 2.34% XSWX: 2.32% XAMS: 1.90% XMIL: 1.90% LSE2: 1.86% XLIS: 0.62% XSTO: 0.62% XHEL: 0.52% XNMS: 0.38% XOSL: 0.28% XBRU: 0.17% XSES: 0.11% XCSE: 0.03% XIOB: 0.02% XVIE: 0.02% XDUB: 0.01%

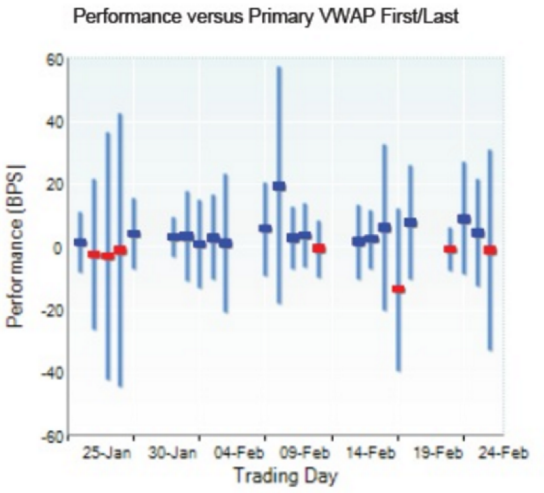


Performance Summary

Performance Benchmark	All	Buys	Sells
Market VWAP First/Last	1.88	-1.55	5.26
Primary VWAP First/Last	1.93	-1.40	5.22
Market Daily VWAP	7.46	-8.31	22.86
Primary Daily VWAP	1.93	-1.40	5.22
First Fill (mid)	-38.66	-93.43	26.46
Previous Closing Price	22.94	14.66	31.04
Closing Price	1.41	4.72	-1.82

Performance versus Primary VWAP First/Last

Average Improvement/Shortfall	1.93BPS
Standard Deviation	23.12BPS



Source: LiquidMetrix

Post-Trade TCA - Examples

Activity				Execution Quality		BPS	Performance		BPS	Timing					
	Total	Buys	Sells												
Count	4,710	2,654	2,056	IS	10,390,311	50	vs Interval VWAP	-6,125,763	-30	vs 3 Months Before	-21,608,390	-104	vs Next Day	-6,765,176	-32
Ordered Shares	981,927,686	664,780,333	317,147,353	Expected Cost	11,774,811	56	vs Open	-12,374,361	-59	vs 1 Month Before	5,755,420	27	vs 2 Days After	-5,514,169	-26
Ordered Amount	2,093,944,861	1,134,473,507	959,471,354	Performance	1,384,501	7	vs Close	-9,006,591	-43	vs 1 Week Before	-9,407,428	-45	vs 1 Week After	-8,195,449	-39
Executed Shares	981,927,686	664,780,333	317,147,353	Opportunity Cost	0	0	vs Price at End	-9,216,447	-44	vs 2 Days Before	-20,112,450	-95	vs 1 Month After	930,808	4
Executed Amount	2,130,533,949	1,153,471,350	977,062,599	Opportunity Cost 'End'	0	0	vs VWAP	-10,188,174	-49	vs 1 Day Before	-14,486,893	-69	vs 3 Months After	8,375,598	39
Order Life Average	388			Opportunity Cost 'Client'	0	0	vs Interval High	739,719	4						

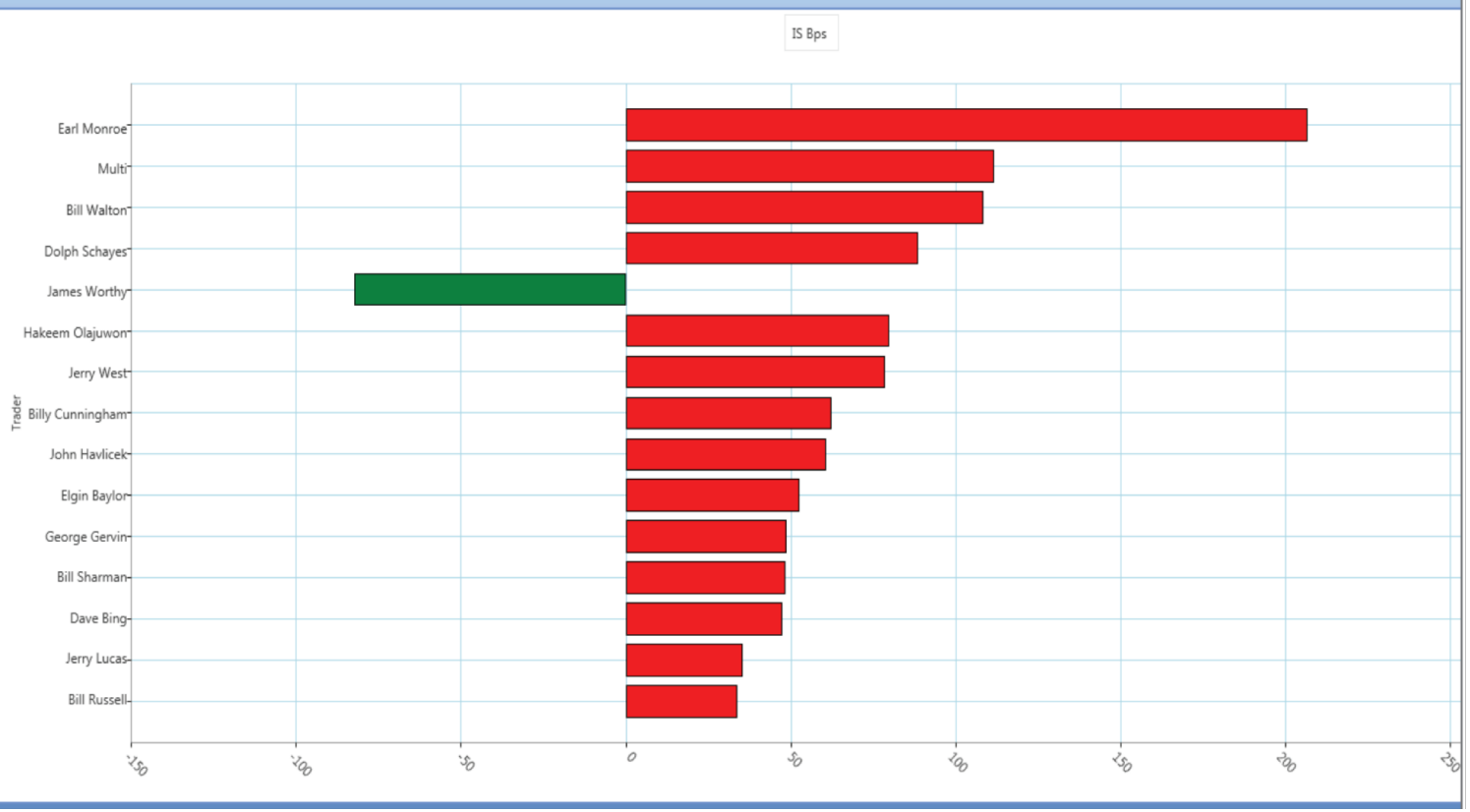
Comparison | Trade Timing | Date Range | XY Chart | Simple Alpha | Histogram | Participation | Spreadsheet

Click here to hide chart options

Select Grouping: Manager, Trading Team, Trader, Broker, Algorithm, Side, Strategy, Style, Sleeve, Account, Amount Order, Liquidity, Market Cap, Participation, PerformanceBi, Sector, Security, Country, Country of Risl, Region, Currency, Order Id, MKT/LMT, DAY/GTC, Order Type, Start Time, Cross/Non-Cro, Program/Non-, Program ID

Graph — Benchmarks (bps): 7.5% PWP, 10% PWP, 15% PWP, 20% PWP, 25% PWP, Close, Client, Custom, Interval Best, Interval High, Interval Low, Interval VWAP, Interval VWAP Overlapping, Interval Limit VWAP, Interval Worst, IS, IS Plus Opp Cost, Open, Opportunity Cost, Opportunity Cost 'End', Opportunity Cost 'Client', Performance, Index Performance, Previous Close, Price at End, TCA Used, VWAP, Generated to Close VWAP, Generated +5 min, Generated +30 min, Price at End +5 min

Build Report



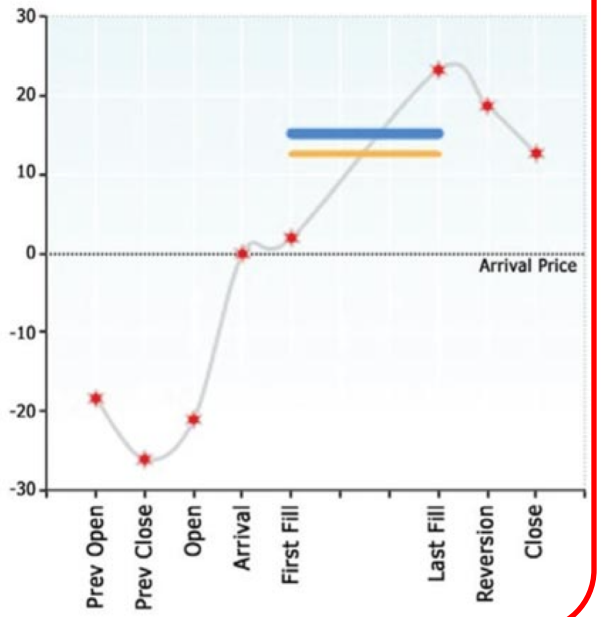
Source: Charles River

Post-Trade TCA – Examples

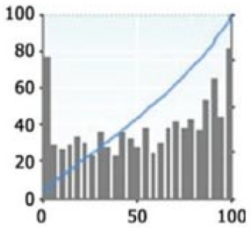
Figure 2:

Macro performance for 6-7 hours **Orders: 100** **Value: €83,344,193** **Avg duration: 06:24:42**

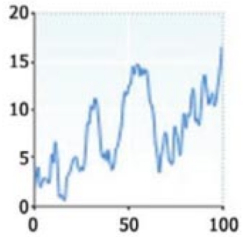
Macro chart:



Fill rate:



Price Impact:



Macro summary:

VWAP (First/Last):	**-2.62 BPS**
Spread Capture*contribution:	+0.09 BPS
Timing contribution:	-2.72 BPS
IS (Open)	**-35.95 BPS**
Opportunity Cost contribution:	-20.74 BPS
Delay Cost contribution:	-2.12 BPS
Spread Capture* contribution:	+0.09 BPS
Impact Contribution:	-13.18 BPS
Participation/Reversion	
Participation Rate:	19.07%
Reversion(15min):	-4.54 BPS
Front Loading:	24%-21%-24%-31%
Market Dynamics	
Alpha (Day of Trade):	+34.24 BPS
1 Day Momentum:	-9.69 BPS
5 Day Momentum:	+16.42 BPS

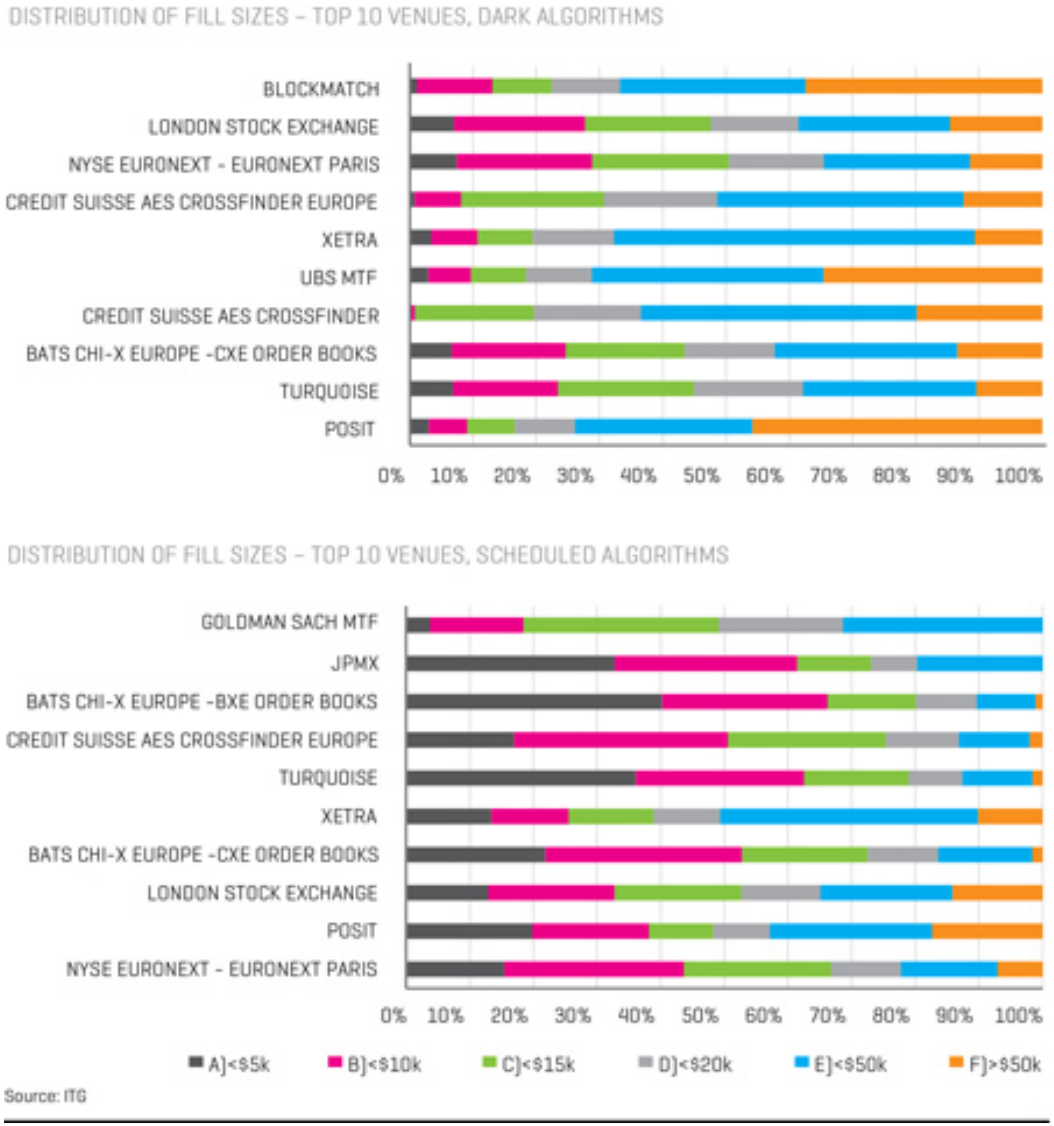
(*)Based on 50.77% spread capture and 11.92 BPS average spread.

Source: LiquidMetrix

Execution Venue Analysis

- Distribution of Executions between Venues
- Execution Size (bigger is better)
- Slippage (from what?)
- Adverse selection / Reversion

FIGURE 2
EU Examples of Average Fill Size by Venue Type and Strategy



Source: ITG

Execution Venue Analysis cont'd.

FIGURE 3
EU Implementation Shortfall Cost by Venue Type and Strategy

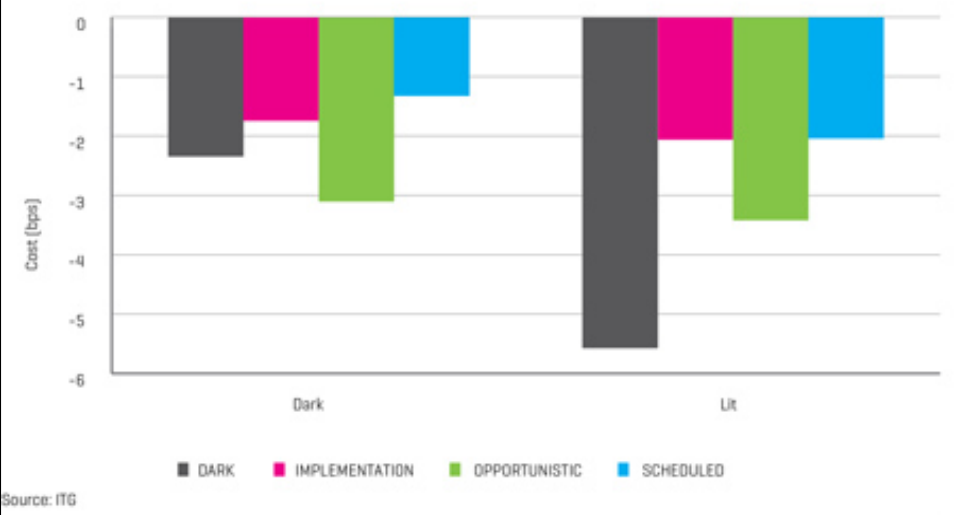
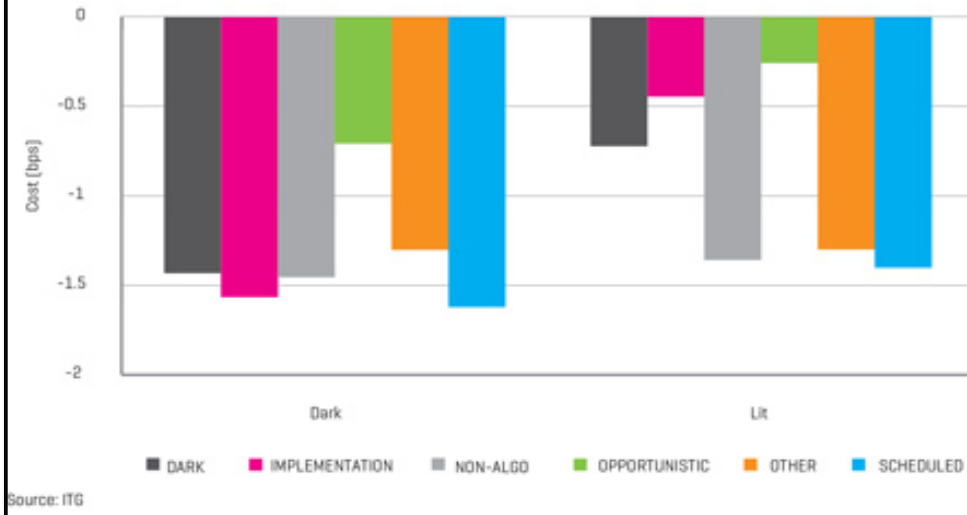


FIGURE 4
One Second Post Trade Reversion by Venue Type and Strategy in the EU



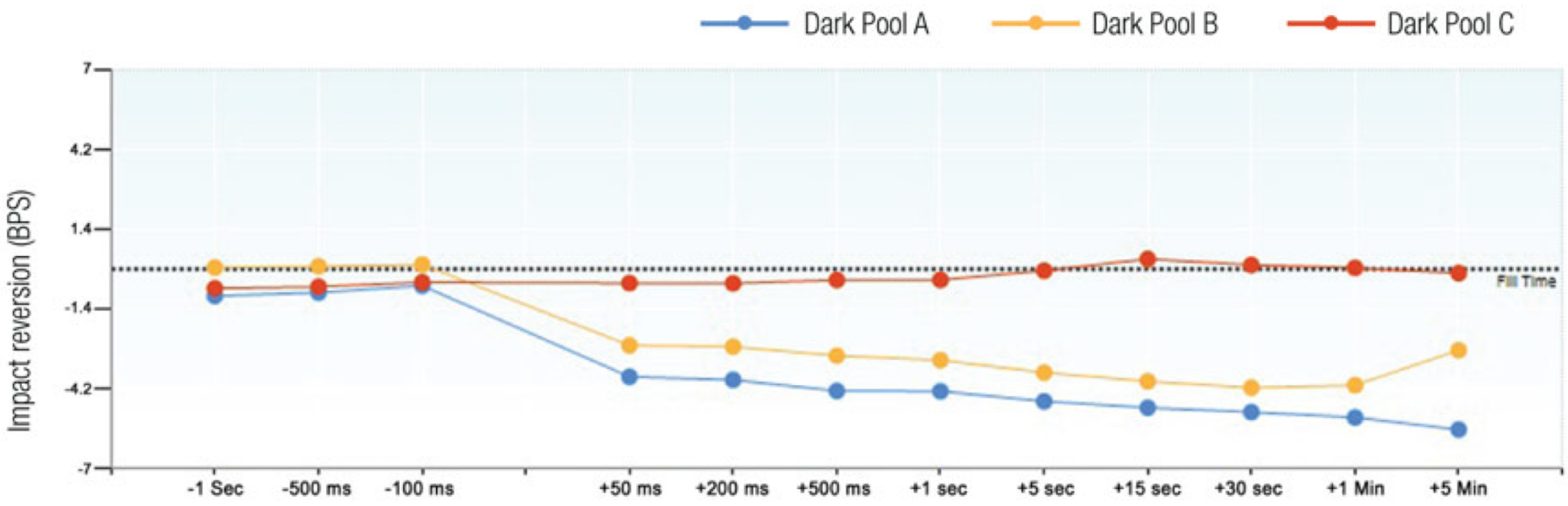
Source: ITG

- Slippage from arrival – causality?
  - Multiple venues
  - Overlapping orders
  - Decoupling timing from order placement is impossible

- Adverse selection / Reversion
  - What happened after the trade?
  - Excess Reversion is bad (could have traded better later)
  - Momentum = information leakage?

Execution Venue Analysis cont'd.

Figure 5: High frequency price movements just before and after fills



Source: LiquidMetrix

TCA Considerations and Best Practices

- Normalizing results across brokers, algorithms and market conditions
- Broker specific report formats (we have seen several just today)
- How is arrival price defined?
  - Last trade? Midpoint at arrival? Weighted?
  - What if the stock hasn't traded yet at arrival? (pre-open)
  - What if stock is illiquid? Is last trade or current midpoint better?
- VWAP
  - What prints are included / excluded?
  - Primary (common in Europe)
  - Consolidated (better in US?)
  - Is Auction volume included?
- Measurements of reversion / adverse selection
  - Time resolution of price movement – seconds, milliseconds?
- Venue identifiers (last Market – includes routed orders?)

TCA Considerations – Data Analytics

Key challenges in data management and analytics

- Large volume of data
  - Billions of records on stock quotes and trades
  - Large volume of client orders and executions with millions on records

- Trade-Quote Matching
  - Which trade refers to which quote? Not a simple match!
  - Lee-Ready algorithm a popular choice – Add 5 second delay to quote to match a fill

- Real-time analytics
  - Live market data feed to perform benchmark analysis
  - Latency in both market data feed and client order data

Execution Strategy Types

Trading Strategy Taxonomy

- Execution: Given instructions (buy/sell, instrument, price, quantity, style/benchmark), achieve an execution objective.
  - Execution "Algorithm" – when to trade, achieve a benchmark
  - Smart Order Router – where to trade, choose between trading venues
- Market-making: concurrently place orders to buy and sell a security
  - Capture spread
  - Earn rebates
  - For our purposes Indications of Interest (IOIs) also fall into this category
- Hedging: Given some risk metric trade to reduce said risk
  - For example the delta of a portfolio of equities
  - Buy delta when portfolio is short delta, sell delta when portfolio is long
- Multi-instrument strategies (pairs, portfolios)
  - Trade multiple securities concurrently
  - Maintain a relationship, e.g. $ neutrality (similar to hedging)
  - Statistical arbitrage, e.g. buy/sell securities when the relationship diverges from the expected
- "Alpha" strategies: some capability to forecast asset prices, either directly or in relationship to others. In our taxonomy these are purely "pricing" and still require execution.

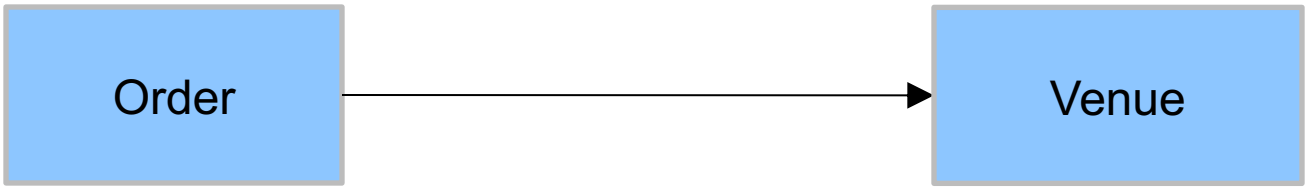
Execution Objectives Restated

- Minimize impact: avoid signaling your intent to the market
- Achieve a benchmark (PM determined)
  - VWAP, TWAP, Open, Close, PWP, etc.
  - Benchmark used to distinguish alpha from execution
- Manage explicit execution costs
  - Minimize fees
  - Maximize rebates
- Portfolio trade
  - Maintain neutrality or specific skew (cash, sector)
  - Raise cash

Execution Strategy Sub Types

- Direct Market Access (DMA)
- Order Routers: “Smart Order Routers”, Dark liquidity aggregators
- Schedule-Based: VWAP, TWAP
- Volume-Following: Percent of Volume
- Implementation Shortfall: minimize difference from arrival price by balancing market impact and opportunity cost
- Event Driven / Liquidity Seeking: Sensitive to spread, order book size, may use quantitative models
- Pairs
- Higher-Order Activities
  - ✓ Portfolio
  - ✓ Hedging, Market Making
  - ✓ Statistical Arbitrage

Direct Market Access (DMA)

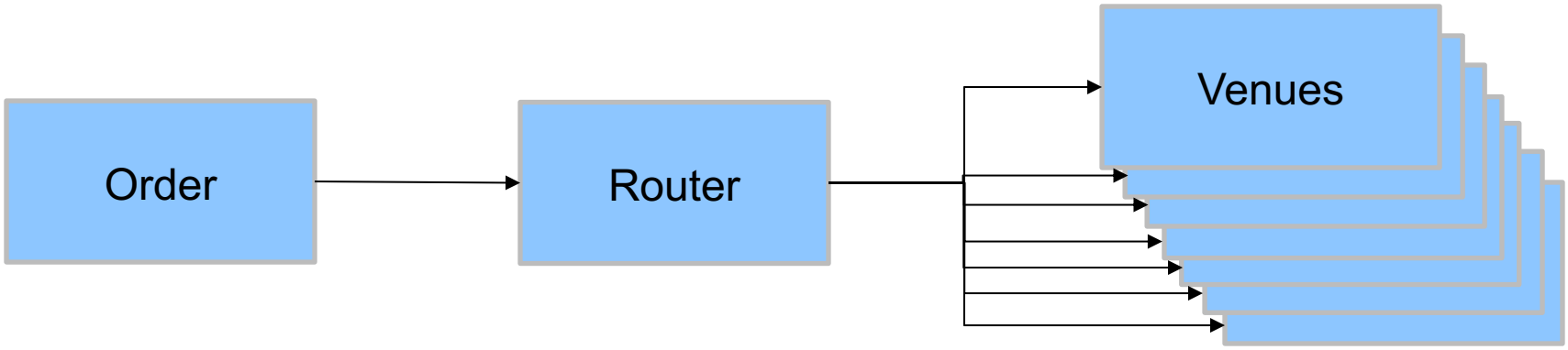


Objectives

- Send a single order to a single market venue
- Simple, Fast Order Placement

- Pros
  - Fast access to market
  - Simple
- Cons
  - Trader must select venue
  - Practical limits to order size
  - RegNMS (in US)

Order Router



"Smart Order Routers"

Dark Liquidity Aggregators

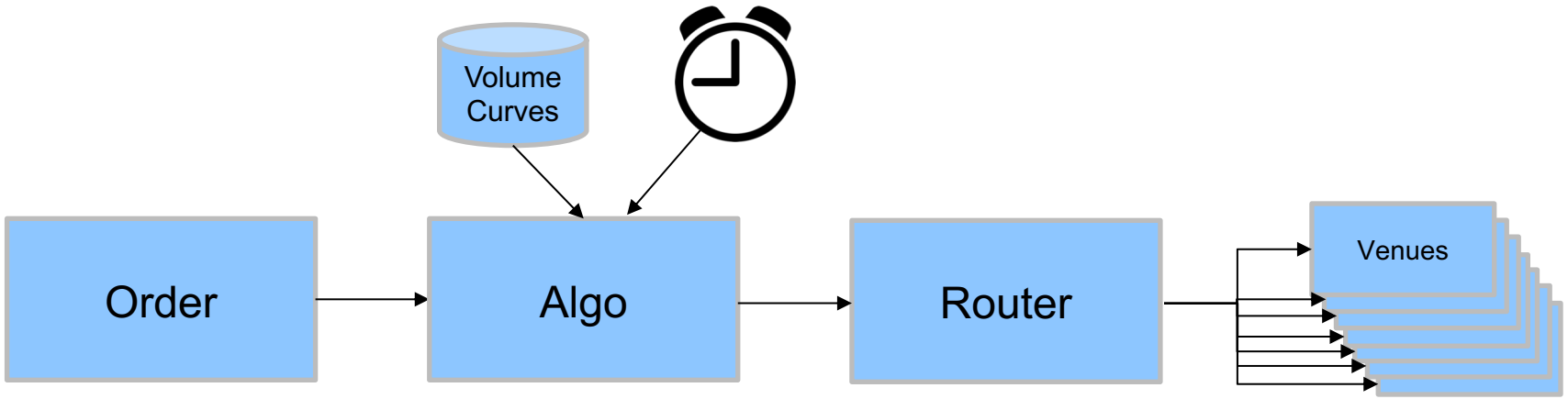
Objectives

- Send a single order to multiple market venues
- Fast "Optimal" Order Placement

Splits order into multiple child orders

- Pros
  - Venue Access Included
  - Handles Issues like RegNMS
- Cons
  - Trader must select venue
  - Practical limits to order size

Schedule Based

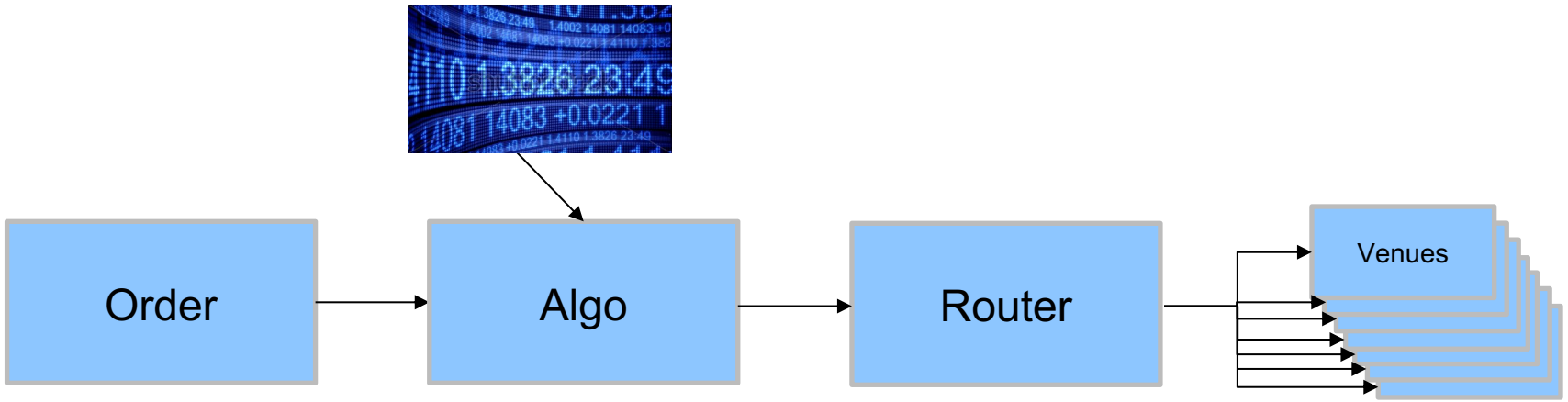


Objective: Match or beat a time-based benchmark, e.g. TWAP or VWAP

- Separate algo and router
- Typical Parameters
  - Start, End time
  - Limit price
  - Volume cap

- Splits order over time based on a schedule
- Pros
  - Handles much larger orders
  - Reduced impact
- Cons
  - Opportunity cost
  - Not reactive

Volume Following

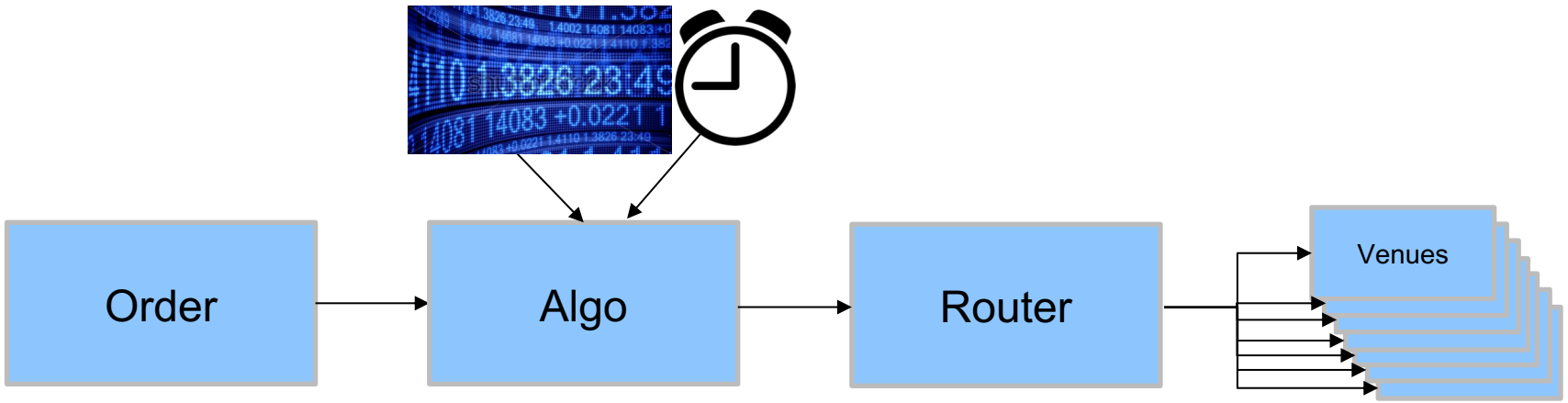


Objective: participate in market flow at some predetermined rate

- Typical Parameters
  - Min % of Volume
  - Max % of Volume
  - Limit Price

- Pros
  - Handle large orders
  - Responsive to volume changes
  - "No one ever got fired for following VWAP"
- Cons
  - Somewhat responsive but still dumb
  - Opportunity cost

Implementation Shortfall



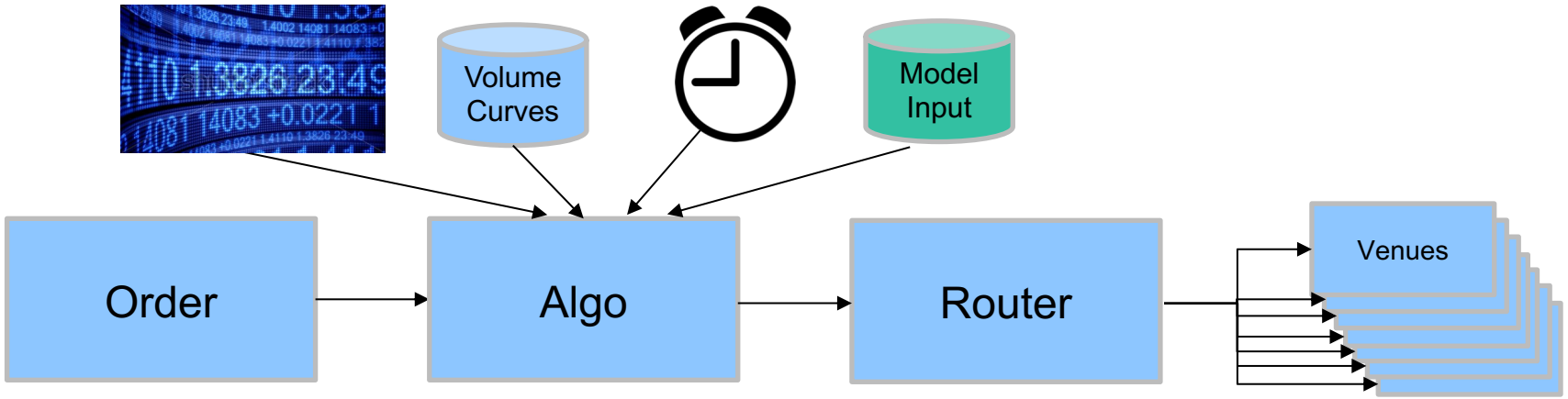
Objective: balance market impact and opportunity cost, benchmark = arrival price

- Typical Parameters
  - "Urgency" – a static set of rules that range from passive to aggressive by modulating participation rate and other parameters
  - Limit Price
  - Max % Volume

- Pros
  - Handles Larger orders
  - Fine tuned performance

- Cons
  - Rules based behavior smarter but still not responsive to market conditions
  - Inflexibility often requires customization

Event Driven / Dynamic

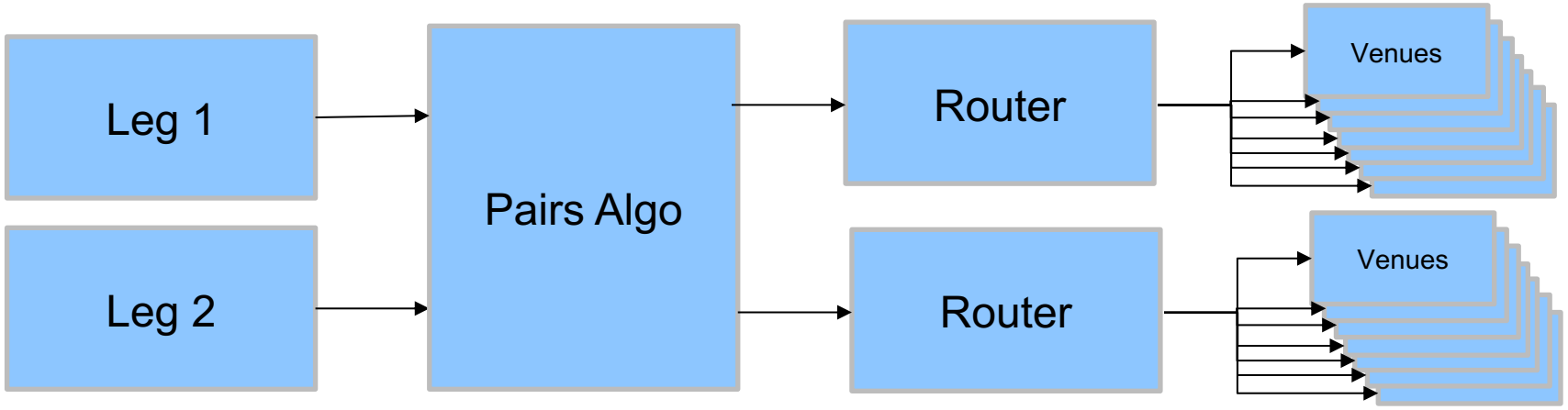


Objective: Optimize execution for <u>current market conditions</u>

- Typical Parameters
  - Urgency – define a range of behaviors based on certain parameters
  - Max % of Volume
  - Spread sensitivity
  - Liquidity Sensitivity
  - Limit Price

- Pros
  - Responsive to volatile conditions
  - Good for illiquid names
  - Arrival price benchmarking
  - Large orders
- Cons
  - Behaviors less obvious
  - Decomposing performance can be more difficult

Pairs



Objective: trade two securities in parallel, maintaining some relationship

Example:

Buy $50K GOOG

Sell $50K AMZN

Uses

- Transition between Securities
- Arbitrage

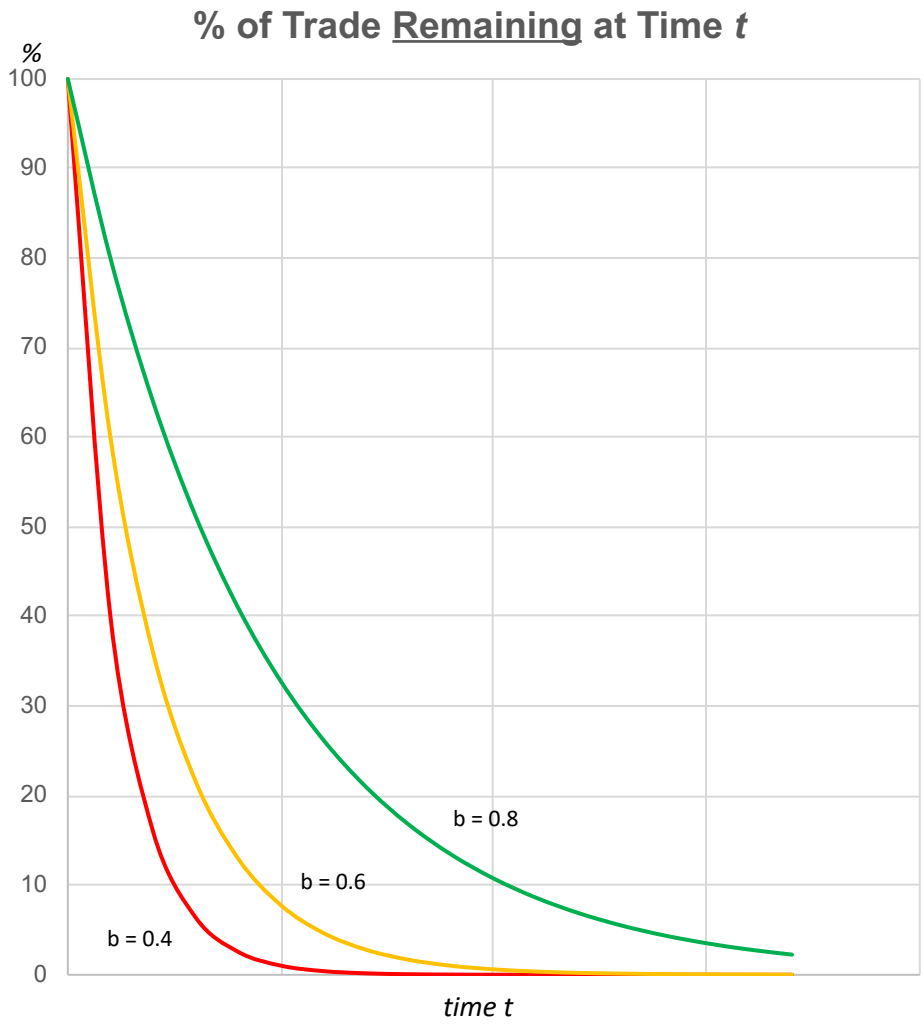
Example Relationship / Strategies

- $ Neutrality: trade equal amounts over time until complete
- Spread: only trade when the spread between them

Implementation Shortfall

Opportunity cost / impact trade off

- Common parameters
  - Volume caps
  - Aggressiveness / patience (tuning the tradeoff)
- Models vs. heuristics
- Cleanup
  - Order has to finish eventually!
  - Size Thresholds
  - Minimum % volume



where

$a=100,\ 0 <= b <= 1,\ t = time$

Case Study: Basic Execution Strategies

L3.1 TWAP.ipynb
L3.2 Percentage of Volume.ipynb