

VWAP Strategies

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It is common to evaluate the performance of traders by their ability to execute orders at prices better than the **volume-weighted average price (VWAP)** over the trading horizon. Berkowitz, Logue, and Noser [1988] regard the VWAP benchmark as a good approximation of the price for a passive trader. Its computational simplicity is a major advantage, especially in markets where detailed trade level data are difficult or expensive to obtain. VWAP benchmarks are prevalent outside the U.S., especially in Japan and continental Europe.

A trader's order placement strategy, trading horizon, and execution venue are affected by the criteria used to measure performance. In turn, these decisions have an impact on transaction costs and risk, and hence on realized alpha. Consequently, the widespread use of VWAP benchmarks raises several natural questions:

1. When is VWAP a sensible benchmark, and how does it compare with alternatives?
2. How do traders adjust their trading strategies when they are measured against a VWAP metric?
3. What are the advantages and disadvantages of alternative strategies (forward VWAP crosses, automated participation strategies, guaranteed VWAP bids, and agency trading) to achieve execution close to VWAP?

To examine these questions, I begin by

reviewing the logic of a VWAP benchmark and the extent to which it can be meaningfully defined. The uncritical use of VWAP as a benchmark can promote trading behavior that actually increases costs and risk. **VWAP is a reasonable benchmark for smaller trades that lack urgency and when traders do not have discretion over timing or execution.**

I discuss three possible trading strategies to achieve a VWAP benchmark, including **selling the order to a broker-dealer who guarantees VWAP; crossing the order for execution at a future date at VWAP; and trading the order to achieve the benchmark or better.** These alternatives are shown to differ considerably in important dimensions, including tracking error, overall cost, and complexity. An especially attractive alternative is an automated VWAP strategy.

While VWAP strategies are conceptually straightforward, their implementation is more difficult than commonly believed. Traders and portfolio managers should exercise considerable caution when trying to achieve VWAP benchmarks.

BENCHMARK PRICES

Trading costs are usually computed by comparing the average realized transaction price against a reference or benchmark price. The most common benchmarks are weighted averages of prices and quotes around the trade. Three types of benchmarks are used:

EXHIBIT 1

VWAP Definitions

Measure	Definition	Remarks
Full VWAP	Ratio of the dollar volume traded to the corresponding share volume over the trading horizon, including all transactions	Standard definition, usually computed the day of the trade. Some traders use multiday VWAP (in the case of orders broken up for execution over several days) or intraday VWAP for orders executed strictly within the trading day. Unambiguously defined.
VWAP excluding own transactions	Ratio of dollar volume traded (excluding own volume) to share volume (excluding own volume) over the trading horizon	When the trader's order is a large fraction of volume, excluding the trader's own transaction volume corrects for bias. Excluding own trades, however, may produce a misrepresentative benchmark since VWAP is an average of prices before and after the bulk of the trading has occurred.
Non-block VWAP	VWAP computed excluding upstairs or block trades	Excluding large-block trades is reasonable for small traders who cannot access upstairs liquidity (Keim and Madhavan [1996]; Madhavan and Cheng [1997]). While some markets flag upstairs trades, others including those in the U.S. do not. It is common to exclude trades of 10,000 or more shares as a proxy for upstairs trades.
VWAP proxies	Proxies for VWAP, including simple average of open, low, high, and close	In emerging markets where tick-level data are unavailable, proxies are readily computed.
Value-weighted average price	Prices weighted by dollar value of trade, not share volume.	Value-weighting is reasonable for volatile securities because the weights are determined by the economic value of the transaction. Other weighting schemes also exist.

1. *A weighted average of prices over the trading horizon, typically full-day or part-day VWAP.*¹
2. *Post-trade prices* that place all the weight on prices *after* the trade, typically on the day's close.
3. *Pre-trade prices* that place all the weight on prices *before* the trade, including measures such as the previous day's close, open, last trade, or the midpoint of bid-offer at the time of the first trade of the order.

The theoretical justification for a VWAP benchmark comes from Berkowitz, Logue, and Noser [1988], who advocate a weighted average of transaction prices on both sides of the trade as an unbiased estimate of the prices facing a non-strategic trader during the day of the trade. Many definitions of VWAP, however, are used in actual practice.

Exhibit 1 summarizes the various definitions of VWAP commonly used and their relative merits.

BENCHMARK CHOICE AND TRADING STRATEGY

The choice of performance benchmark will affect a trader's decisions regarding order placement strategy (limit versus market orders), trading horizon, and venue (primary market, upstairs market, crossing systems) among other factors. These decisions in turn have a significant impact on realized trading costs, and hence net alpha. Choice of benchmark has implications for a trader's actions with respect to the three major categories of benchmarks.

In the case of volume-weighted average price benchmarks, the major impact on strategy has to do with trading horizon. Daily VWAP benchmarks encourage traders to spread their trades out over time to avoid the risk of trading at prices that are at the extreme for the day. This practice entails significant risks, because delay and opportunity costs arising from passive participation trading can significantly erode alpha. It also favors the use of market orders rather than limit orders to ensure timely execution,

EXHIBIT 2

VWAP Strategy Alternatives

Strategy	Providers	Advantages	Disadvantages
Guaranteed principal VWAP bid	Major broker-dealers	Low commission, guaranteed execution.	Exposure to significant adverse price movements; leakage of information, especially in thinly traded stocks.
Forward VWAP cross	Ashton Technology Group, Instinet, others	Low commission, no market impact.	Non-execution risk; residual must be traded. Exposure to significant adverse price movements.
Agency trading or direct access	Major broker-dealers	Control over trading process, including ability to cancel during day.	VWAP is not guaranteed. Commission costs; ticket charges add up. Significant time commitment.
Automated participation strategy	ITG SmartServer™, FlexTrade, Madoff, others	Ability to cancel during day; low cost. Can be somewhat customized.	VWAP is not guaranteed. Possibility of significant shortfalls on days with unusual price or volume patterns.

which, although offering the opportunity to earn the spread, risks non-execution.

A related issue arises with choice of venue. Traders might avoid seizing opportunities that arise to liquidate a large portion of the order in a block or a cross for fear of executing away from VWAP. Often these systems (including crossing networks or upstairs markets) provide execution for large blocks at very low cost. For large-block trades in less liquid securities, VWAP essentially reflects the trade itself. In these cases, there is little incentive for a trader to expend effort to control costs or to seek out low-cost methods of execution.

VWAP benchmarks also underestimate costs relative to pre-trade benchmarks when the stock itself is trending—if the stock price is rising while the trader is buying, for example (see Lert [2001]). Again, traders are not given the incentive to trade aggressively early on to minimize opportunity costs.

Criticisms regarding gaming are especially relevant for volume-weighted average price benchmarks, although to some extent they apply to all benchmarks except pure pre-trade measures. In the case of VWAP, giving a trader

latitude over the timing of the trade adds to risk, especially in two-sided or dollar-balanced trades, because the trader could game the measure to achieve superior measured performance by selectively executing those portions of the list that are most favorable.

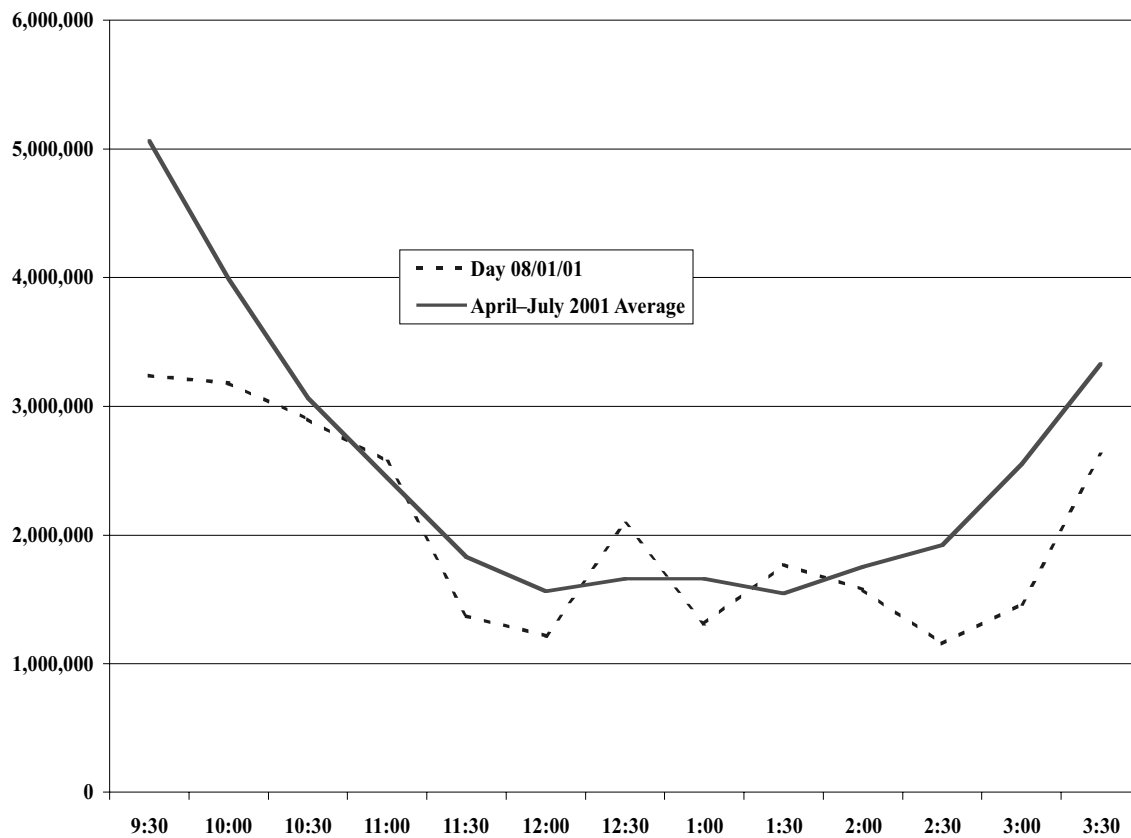
Other benchmarks also have an influence on trading strategy. Post-trade benchmarks are often used by traders concerned about tracking error relative to the close, such as index funds. Although simple, this benchmark promotes trading at the close, either through placing market orders toward the end of the day or through guaranteed market-on-close orders.

Trading at the close involves hidden costs that can be significant. Cushing and Madhavan [2000] show that prices are more sensitive to order flows at the close, implying greater price impacts.² Returns exhibit significant reversals on days with published imbalances (100 basis points or more), indicating that traders who demand liquidity at the close pay a significant premium.

Traders seeking closing prices are also unlikely to use passive strategies that offer the potential to reduce trading costs (crossing systems, limit orders). Finally, post-trade

EXHIBIT 3

Microsoft Corporation Share Volume by Time of Day—April–July 2001



benchmarks are also more subject to gaming than pre-trade benchmarks (since there is no incentive to minimize the permanent price impact component).

Pre-trade benchmarks are theoretically preferred when the measure is the implementation shortfall approach (Perold [1988]). In this approach, trading cost is the difference between the returns to a notional paper portfolio formed at the price prevailing at the time of the decision to trade. The implementation shortfall approach has strong theoretical support and allows a separation of implicit trading costs into its components (timing, delay, impact, and opportunity costs) as in Edwards and Wagner [1993].

To the extent that the benchmark is determined before the trader receives the order, it cannot be gamed, and correctly creates incentives for the trader to minimize transaction costs. The drawback is that in practice the decision price is difficult to capture and is often proxied for by the previous day's close or the price before the first trade of a sequence of orders. Given that these prices are noisy

proxies for the decision price, this complicates the task of measuring costs and trading performance using a pre-trade benchmark.

TRADING STRATEGIES TO ACHIEVE VWAP

While VWAP benchmarks are not always appropriate, especially for traders motivated by short-term momentum or orders that are a significant fraction of daily volume, they are simple. VWAP thus remains a popular benchmark to measure the performance of traders and to compute trading costs. Taking the VWAP benchmark as given, what trading strategies can be adopted, and what are their relative merits?

Essentially, the VWAP strategies fall into one of three categories: *Sell* the order to a broker-dealer who guarantees VWAP; *cross* the order at a future date at VWAP; or *trade* the order with the goal of achieving a price of VWAP or better:

1. *Guaranteed principal VWAP bid*, where a trade list is given to a broker-dealer who charges a fixed per share commission and guarantees the day's VWAP for each stock.
2. *Forward VWAP cross*, where buyers and sellers are matched electronically and execute at the end of the day at a price equal to full-day VWAP.
3. *VWAP Trading*:
 - Direct access, where the order is traded by the investor, either through a participation strategy or with a view to time the market to beat VWAP.
 - Agency trading, where the order is given to a broker-dealer to trade on an agency basis with the aim of obtaining VWAP or better.
 - Automated participation strategies, where orders are broken up over the day to participate proportionately in the day's volume, trading as intelligently as possible and with minimal market impact.

Exhibit 2 summarizes the main alternatives, the primary providers of a service, and the advantages and disadvantages. The alternatives are not all alike. Indeed, there are possibly significant differences that relate to several key questions: Is VWAP guaranteed? What are the costs—both implicit and explicit—of the strategy? How much control does the client have over the trading process?

Guaranteed Principal VWAP Bid

Guaranteed principal VWAP bid offers the most certainty, since execution is guaranteed at VWAP for a fixed per share commission, and the broker-dealer assumes the entire risk of failing to meet the benchmark. While the explicit cost in commission terms is often attractive (occasionally free), the true cost of the guaranteed VWAP bid could be very high. Essentially, the broker-dealer is taking on the risk of the trade and hoping to profit by executing at prices better than VWAP.

This might happen in a variety of ways. First, the broker-dealer might cross some portion of the list internally, providing some margin. The client's trade list might well include names that the broker-dealer seeks to take the same position in, however, so this rationale cannot fully explain the profitability of guaranteed VWAP transactions.

Second, the broker-dealer benefits from knowledge of the client's flows. In active stocks, this information might not be that helpful, but in inactive stocks, where orders are likely to move prices, knowledge of order flows and intentions is very valuable.

The subtlety here is that the VWAP computed under a principal bid strategy is different from the VWAP realized using agency trading or direct access. The difference is the compensation to the broker-dealer for incurring the principal risk. While not immediately visible, this cost is very real.

Forward VWAP Cross

Forward VWAP crosses offer potentially the lowest-cost alternative, not necessarily in commission, but in terms of total cost. Various providers offer this service for a fixed per share commission, as discussed by Uchimoto [2001]. Crossing allows both buyers and sellers to avoid price impact, which is usually significantly higher than the commission cost.

The primary drawback to a forward cross is that it precommits the trader to execute at a price that is not known in advance. Indeed, both sides face a loss of control in the form of price risk in the event of a significant market movement.

A further drawback is that execution probabilities are typically low, and the unmatched portion of the order must still be traded somehow. Finally, there is the possibility of adverse selection, where the probability of crossing is higher for traders without private information, and the price movements given a cross are unfavorable to the trader.

VWAP Trading

In VWAP trading, clients can either trade the order themselves (direct access), or give it to a broker-dealer to execute on an agency trading basis. Trading the order, either directly or on an agency basis, provides the most control. Control in this case refers to price protection via limit prices, the ability to stop or cancel trading during the day, and choice over where the order is traded or how (e.g., whether to use limit or market orders). Manual trading is labor-intensive and hence may not be the cheapest alternative.

Typically, the order is broken up for execution over the day to participate proportionately in the day's volume. Fine order breakup yields a better approximation to VWAP, but at the cost of higher ticket charges and commission fees.

A VWAP strategy based on participation will typically miss VWAP on average. To see this, recognize that traders with valuable information (e.g., fast day traders who hit stale quotes when news events occur) will earn posi-

tive profits, on average, and a participation strategy will typically miss out on such trades. The only way to recoup these losses is for the strategy to act as a liquidity provider, using limit orders to make the spread instead of paying for immediacy.

Control of transaction costs is the key to minimizing the shortfall from VWAP. Alternatively, traders might try to make use of their specific knowledge of market conditions to beat VWAP. Some agency brokers are compensated on the basis of how much they beat the VWAP benchmark, providing an incentive to minimize trading costs.

The newest method of achieving VWAP is to use automated trading strategies to participate proportionately throughout the trading day, trading as intelligently as possible and with minimal market impact. Several vendors offer so-called autotrading systems that can be programmed to send orders to the market according to a pre-specified algorithm. For example, orders can be split up for execution over the day in accordance with the historical volume “smile” or pattern.

The problem with such a strategy based on time patterns is that the volume pattern on any given day can depart significantly from the historical average.

Exhibit 3 shows the relative volume pattern (ratio of volume in each of 13 half-hour bins to average daily volume) for a two-month period (April-July 2001) and a single day, August 1, 2001, for Microsoft Corporation stock. The historical pattern is U-shaped, as is the volume pattern on August 1, 2001, but the single day exhibits greater variation. Specifically, less was traded (as a fraction of the day’s volume) in the opening half-hour on August 1 than has historically been the case, implying that a simple time-slicing algorithm might miss VWAP during the morning period.

The variation around the historical distribution is also likely to differ considerably across stocks, so that errors are more likely in thinly traded stocks than in highly liquid stocks like Microsoft. Using finer time grids can avoid such problems, but necessitates more complex automation to forecast changes in the historical volume pattern dynamically.

Given a forecast of the historical volume pattern, the logic governing execution within a given time bin is critically important. Overly passive trading offers the potential to beat VWAP (by earning the liquidity premium as opposed to paying it), but increases the tracking error around VWAP since execution is not guaranteed. Trading aggressively using market orders can better track the

volume pattern but incurs higher transaction costs in the form of market impact. The more advanced automated strategies embody these types of considerations.

ANATOMY OF AN AUTOMATED VWAP STRATEGY

An automated VWAP strategy is best described using a real-world example. I use the VWAP Smart-Server™ developed by ITG Inc. as the basis for discussion. It offers automated VWAP execution on an agency basis in a large universe of listed and OTC names. The VWAP strategy has three key elements.

Analysis of incoming orders. Pre-trade analysis filters out any orders that would be more appropriately traded using other means. Block trades that are illiquid or very large relative to average daily volume are diverted for manual attention.

Intelligent volume distribution. An accurate estimate of the volume distribution is a key element of a successful automated participation strategy. For each order it receives, the system generates a prediction of the stock’s volume pattern over the desired time horizon, whether full-day or partial-day. A trading distribution is then created to match this projected volume pattern, participating more heavily during the periods of the day when volume is expected to be heaviest. This helps minimize the impact of trading during thin volume periods and allows the order to benefit from the most liquid conditions. As shown in Exhibit 3, such analysis is vital for a participation strategy.

Work orders intelligently. An ability to obtain best execution on individual trades around the expected volume distribution is the last critical element of a successful automated strategy. This VWAP system uses trading rules that balance the desire to trade passively and earn the spread against the need to stay on schedule for each time bin of the day. It actively pursues liquidity, tapping into all available sources and trading most heavily when markets are most liquid.

In addition to accessing exchanges, electronic communication networks, and market makers, the strategy trades passively whenever possible, supplying liquidity to the market through limit orders and submissions to the POSIT equity trade matching system. It takes advantage of internalized order flow, crossing buy and sell orders of the same security at the exact VWAP for the current time period. The use of limit orders and crosses minimizes market impact but risks non-execution.

The timing and pricing of orders is determined according to market conditions, which are monitored continually. When necessary, the within-bin logic of the strategy determines that more aggressive action is required to adhere to the predetermined trading distribution. As shares are filled, reports flow back to the trader for immediate pre- or post-trade analysis. The trader can cancel the remaining order at any time during the day, an especially attractive feature in volatile markets.

As this example makes clear, a successful automated VWAP strategy requires extensive research to create sophisticated rules concerning trade breakup, choice of order type (limit, market, or crossing), trading venue, and so on. This aspect of within-bin logic can also incorporate component mathematical or econometric models (e.g., models of limit order execution that determine optimal limit prices and execution probabilities, or market impact estimators). The result is superior execution for large lists of stocks without the time commitment and expense of manual trading.

The disadvantage, like that of manual trading, is that execution could differ significantly from VWAP if the algorithm is poor or if the market moves significantly against the trader. Continued advances in technology, more accurate financial engineering models, increased automation, and greater list trading all favor this type of approach.

SUMMARY

Traders are often evaluated by their ability to trade at prices better than the volume-weighted average price (VWAP). The choice of benchmark, however, affects a trader's order placement strategy, trading horizon, and execution venue, which influence transaction costs and risk, and hence realized alpha. Alternative strategies have their own advantages and disadvantages. While VWAP strategies are relatively straightforward in concept, their implementation can be difficult.

ENDNOTES

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¹VWAP is defined as the ratio of the dollar transaction volume to share volume over the trading horizon. Often, intraday or multiday VWAP measures are also computed.

²Intuitively, dealers and market makers are less willing to take shares into inventory and bear overnight risk.

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