



## RADFORD BRIEF

### Calculation of Historical Volatility

Expected volatility is one of the most influential assumptions used to determine the fair value of employee stock options, and at the same time, one of the most subjective to set. The most common approach for estimating volatility is through the derivation of historical volatility, which can be calculated using several methodologies. This paper outlines guidance from the regulatory bodies and provides research of alternative approaches for calculating historical volatility by studying each member of the S&P 500. This study can help companies assess the different methodologies for calculating volatility, and the potential for mis-valuation, and align with best practices.

#### A Brief Overview of the Regulatory Guidance

Some regulatory guidance available on calculating historical volatility exists from the original FAS123R, ASC Topic 718, SAB 107, and IFRS2 (all documents are cited at the conclusion of this Brief). In broad strokes, the guidance makes two points consistently: companies should make the determination of the most suitable methodology for their situation and they should use that methodology consistently, from period to period.

Additional direction can be found in the various implementation guides published by each of the major audit firms. We have included a brief summary of the important guidance below. Of course, any decisions about setting a volatility assumption should involve careful consideration of all the regulatory guidance, facts and circumstances, as well as industry best practices.

The objective in estimating volatility is to mirror how a reasonable marketplace participant would do so. ASC Topic 718 states:

*“This Statement does not specify a method of estimating expected volatility; rather, Topic 718-10-55-37 provides a list of factors to be considered in estimating expected volatility.”*

In practice, most companies use a combination or blend of historical, implied and peer volatility in this process. With respect to historical volatility, the regulatory bodies and audit firms provide additional guidance. Topic 718-10-55-37 states that one factor to consider when calculating volatility is:

*“Appropriate and regular intervals for price observations. If an entity considers historical volatility in estimating expected volatility, it should use intervals that are appropriate based on the facts and circumstances and that provide the basis for a reasonable fair value estimate. For example, a publicly traded entity would likely use daily price observations, while a nonpublic entity with shares that occasionally change hands at negotiated prices might use monthly price observations.”*

The citation above is referring to the calculation, as it can be done using daily, weekly, or monthly data points. SAB 107 offers the following guidance when considering which method is best for calculating volatility:

*“Frequency of Price Observations - Statement 123R, paragraph A32(d), indicates an entity should use appropriate and regular intervals for price observations based on facts and circumstances that provide the basis for a reasonable fair value estimate. Accordingly, the staff believes a company should consider the frequency of the trading of its shares and the length of its trading history in determining the appropriate frequency of price observations. The staff believes using daily, weekly or monthly price observations may provide a sufficient basis to estimate expected volatility if the history provides enough data points on which to base the estimate.”*

Further, SAB 107 then explicitly states a preference for weekly or monthly data points in certain circumstances:

*“Further, if shares of a company are thinly traded the staff believes the use of weekly or monthly price observations would generally be more appropriate than the use of daily price observations. The volatility calculation using daily observations for such shares could be artificially inflated due to a larger spread between the bid and asked quotes and lack of consistent trading in the market.”*

Ultimately, because of the subjectivity of this assumption, one of the most important rules to remember is that *“an entity should establish a process for estimating expected volatility and apply that process consistently from period to period”* (Topic 718-10-55-40).

### **The Mathematical Theory**

The higher the volatility, the more expected returns on the shares can be expected to vary – up or down. The calculation of volatility represents the standard deviation of the difference in the natural logarithms of the stock prices plus dividends, if any, over the period. It is typically expressed in annualized terms, which allows for comparisons between daily, weekly, and monthly volatility calculations. Theoretically, with a reasonable sample size, each should converge to the same levels (Topic 718 and SAB 107 both imply that 50 data points should be reasonable, but more data is preferred). However, we often observe that daily volatilities are greater than weekly volatilities, and weekly volatilities are greater than monthly volatilities.

Generally, most option pricing models (Black-Scholes or lattice models) have been developed for the valuation of publicly held exchange-traded instruments, which are held by professionally focused investors. Given their awareness in the market, it can be argued that the use of *daily* stock price data for publicly held instruments is preferred. However, some theorists have suggested that employees are less cognizant of day to day price fluctuations and pay less attention to daily stock price movements than professional traders. Therefore a weekly or monthly stock price volatility may be more appropriate for the valuation of employee stock options.

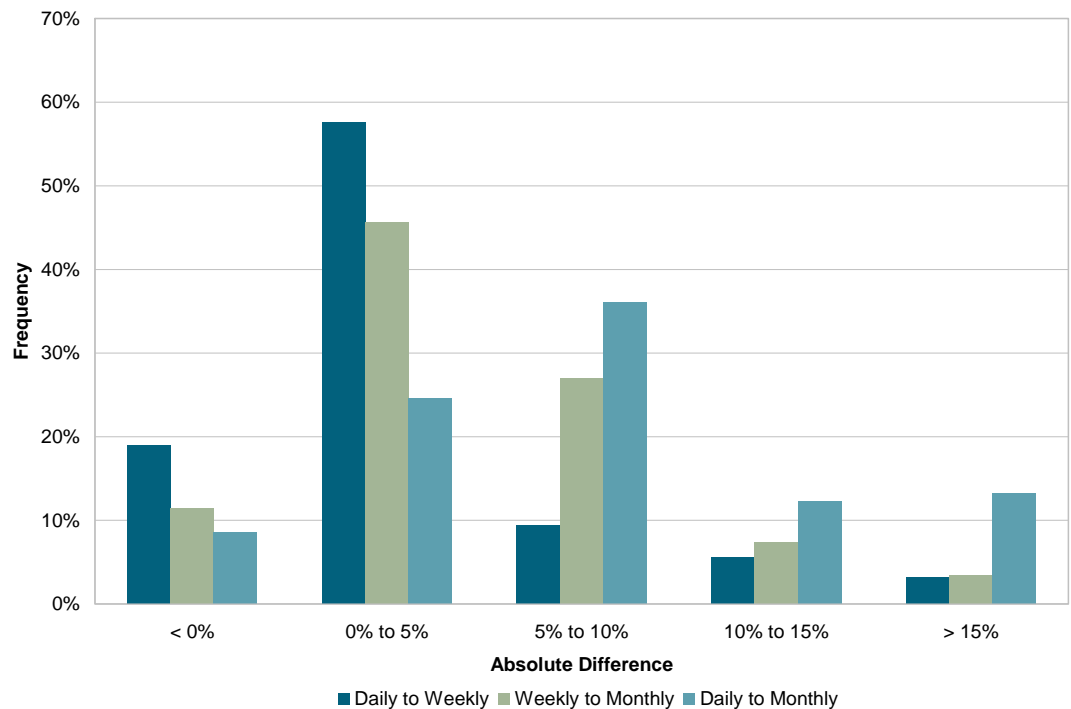
## S&P 500 Research

We have studied companies currently listed in the S&P 500 with regard to their historical daily, weekly, and monthly volatility calculations. Any companies with less than five years of historic prices as of the study date have been removed from this study, therefore yielding 474 companies.

Calculations	Volatility	% Volatility Difference	% of Times Lower than		
			D	W	M
Daily	43.2%	N/A	N/A	19.0%	8.6%
Weekly	40.0%	(7.4%)	81.0%	N/A	11.4%
Monthly	35.5%	(17.8%)	91.4%	88.6%	N/A
Average	39.9%				

While the general trend is for daily volatility to be greater than weekly and monthly, there are a sizable number of exceptions to this simplifying rule.

Chart 1: Distribution of Comparative Calculations

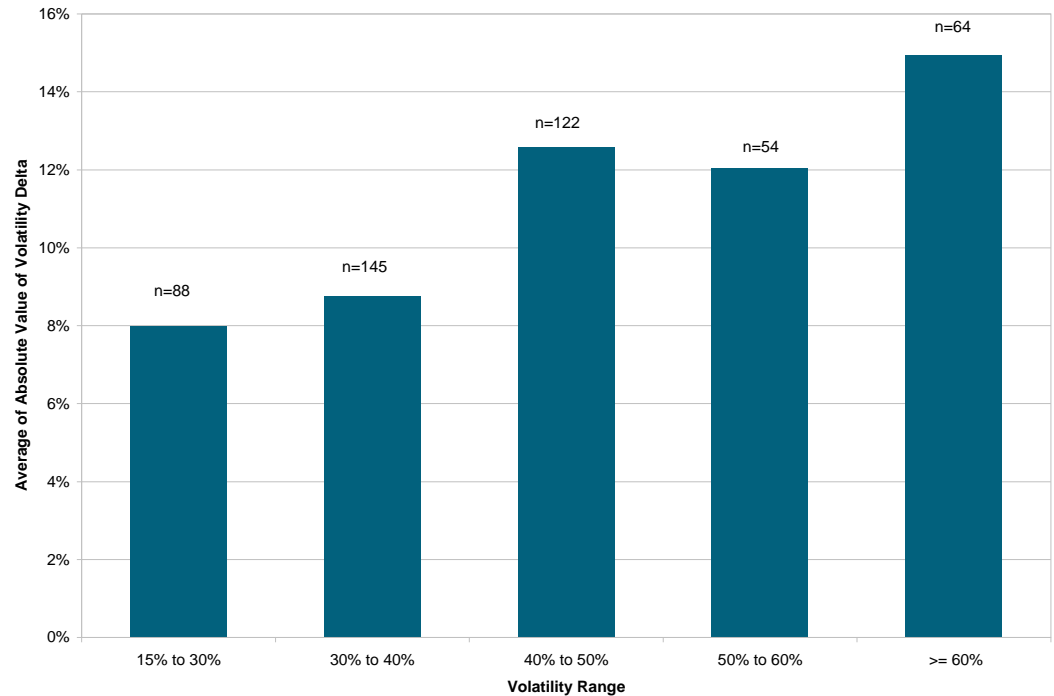


Note that Chart 1 highlights a wide variance of reductions (if any), when analyzing daily vs. weekly vs. monthly volatility calculations. We've also noted the following observations:

- > Daily volatility is lower than weekly volatility 19% of the time;
- > The greatest difference can be seen when comparing daily volatility to monthly, with more than 13% of companies experiencing at least a 15% difference.

One important finding in our study is that companies with higher volatilities tend to have greater relative differences between daily and weekly calculations (see Chart 2 below). This should be of concern to high volatility companies as the use of a daily volatility compared to a weekly volatility could yield larger differences in option valuation.

Chart 2: Differences between Daily to Weekly grouped by volatility levels.



PricewaterhouseCoopers suggests in their audit guide that “when estimates based upon daily and monthly intervals differ significantly, a company may consider using a mid-point volatility estimate by averaging the annualized estimates provided by both daily and monthly data.”

Ultimately, estimating volatility under ASC Topic 718 requires the application of professional judgment based on the facts and circumstances unique to each company.

### Five Days a Week – More Detail on Weekly Volatility Calculations

We also analyzed whether volatility varied meaningfully from one day of the week to another. Best practice in the industry suggests calculating weekly volatility based on Friday data, presumably because this is the close of the week, and also because it is the most accessible data given that it is the export from public data sources.

## Contact Us

For more information,  
please contact:

**James Lecher**  
Assistant Vice President  
+1 (215) 255.1859  
[jlecher@radford.com](mailto:jlecher@radford.com)

**Julia Reeder**  
Associate  
+1 (215) 589.5558  
[jreeder@radford.com](mailto:jreeder@radford.com)

## Locations

Atlanta, Austin, Boston,  
Chicago, Denver, Hong  
Kong, London, New  
York, Philadelphia,  
San Diego, San  
Francisco, San Jose,  
Singapore

Chart 3: Difference between Maximum and Minimum of the days of the week

Day	Average Volatility	Frequency Highest of the Week	Frequency Lowest of the Week
Manic Monday	41.0%	28.3%	7.8%
Tranquil Tuesday	38.8%	2.5%	47.7%
Weepy Wednesday	39.3%	7.4%	29.6%
Thundering Thursday	41.8%	39.7%	4.6%
Friday Funday	41.1%	22.1%	10.3%
<b>Average</b>	<b>40.4%</b>	<b>100.0%</b>	<b>100.0%</b>

Note that the highest average volatility is seen on Thursday at 41.8%, while the lowest average volatility is seen on Tuesday at 38.8%, a difference of more than 7%. We've also studied the absolute difference between the maximum volatility and the minimum volatility during the week. On average, we observed the average difference of approximately 5%.

Despite the fact that material differences in volatility can occur depending on the "day of the week," Radford believes that considerable administrative ease occurs using Friday (most available data sources provide Friday), and that best practice has already been established for Friday. Further, the practice of using alternative days of the week may leave the impression that companies are searching for the lowest answer, and only looking to reduce compensation expense.

## Summary

The calculation of expected volatility, and even historical volatility, requires considerable thought and careful consideration. This Brief highlights a single consideration in calculating historical volatility, one of many considerations. Careful consideration of this issue is warranted, as long-established practices may not currently be the most appropriate, nor currently aligned with existing best practice. Ultimately, estimating volatility under ASC Topic 718 requires the application of professional judgment and should consider many additional data points.

## Citations

Radford has cited the following documents in the above:

- > PricewaterhouseCoopers (PwC), FAS123R, "Share-Based Payment, A Multidisciplinary Approach," February 2006, Second Edition
- > Accounting Standards Codification (ASC) Topic 718
- > Securities and Exchange Commission (SEC), Staff Accounting Bulletin #107

## About Radford

For more than 35 years, Radford has provided compensation market intelligence to the high-technology and life sciences industries. Global survey databases, which include 3.6 million incumbents, offer current, reliable data to more than 2,000 clients. Leveraging Radford survey data, our thought-leading Radford Consulting team creates tailored solutions for the toughest global business and compensation challenges facing companies at all stages of development.

In addition to our consulting team, we also offer Topic 718 equity valuation assistance via Radford Valuation Services, and market-leading analyses and survey services with Radford Analytic Services. For more information on Radford, please visit [www.radford.com](http://www.radford.com).