The Black-Scholes model is a model for the pricing of European-style options. The creation of the Black-Scholes model is commonly delineated as the origin of modern Quantitative Finance.

The utility of the Black-Scholes model does not come from its accuracy at modeling the market price of an option. Rather, it comes from the robustness of the model. The errors of the model are known and follow systematic patterns, such as the **volatility smile**.

In actuality, the model is not used by practitioners to price options. Rather, the market price of an option is taken as given. The model is used to compute the implied volatility of an option. The implied volatility has many uses, including allowing computation of The Greeks (Delta, Gamma, Theta, Vega, and Rho). The Greeks can then be used to hedge an option. For instance, the market price of a call option can be plugged into the Black-Scholes formula to compute the implied volatility. From there the Delta of the option, at that moment in time, can be computed. The Delta then tells the owner of the option how many shares of the underlying stock he needs to buy or sell in order to ensure that his option payoff is guaranteed.

**Parameters and Assumptions of the Black-Scholes Model**

The Black-Scholes model takes in the following parameters:

- The price of the underlying asset
- The strike price
- The date at which the option expires/matures (or, equivalently, the time until expiration)
- The risk-free interest rate

The Black-Scholes model has the following assumptions:

- The option is a European option—i.e., it can only be exercised at the option's maturity date.
- There are no transaction costs.
- The risk-free rate is known and constant over the life of the option.

- The volatility of the price of the underlying asset is constant over the life of the option. The formula in essence assumes that the size of the next move in the asset's price is known, but the direction is not. There are no "jumps" in the asset's price.
- The asset does not pay dividends.
- Market prices are arbitrage-free.
- Trading of the asset is continuous. (i.e., the stock market is always open)
- Fractions of the asset can be traded. (i.e., a half of a share can be purchased)

**Details of the Black-Scholes Model**

The Black-Scholes formula for a European Call Option is:

$$C(S,t) = S_t N(d_1) - Ke^{-rT} N(d_2)$$

Where:

- $d_1 = \frac{\log \frac{S}{K} + (r + v^2/2)\,T}{v\sqrt{T}}$
- $d_2 = d_1 - v\sqrt{T}$
- *N(X)* is the cdf (cumulative normal distribution function), which returns the probability that a normally distributed random variable with mean 0 and standard deviation 1 will be less than or equal to *X*.

The Black-Scholes formula for the price of a European Put Option is:

$$P(S,t) = Ke^{-rT} N(-d_2) - SN(-d_1)$$

The Black-Scholes model has been extended in various papers to relax its assumptions. For instance, Robert Merton extended the model to allow dividends.

The formula for the price of an American call option is the same as for a European call option. This is not the case with put options; the price of an American put can differ from that of a European put. There is not known analytical formula for the pricing of a European put option.

**History of the Black-Scholes model**

Black-Scholes was developed by Fisher Black, Myron Scholes, and Robert Merton. Many refer to it as the Black-Scholes-Merton model. In 1997, Scholes and Merton received the Nobel Prize in Economics for their work on the model. Fisher Black died in 1995, and the Nobel Prize is not awarded posthumously, else he also would have shared in the prize.

The concept that mathematics could be used to price derivative securities was quite revolutionary. Chicago University's Journal of Political Economy and Harvard's Review of Economics and Statistics both rejected publication of the paper in 1970. The paper was finally published by The Journal of Political Economy in 1973 with the title, "The Pricing of Options and Corporate Liabilities." It is said that members of the Chicago faculty had to put pressure on the journal to publish the paper.

The impact of the Black-Scholes model on the derivatives industry was both enormous and rapid. Trading volume at the CBOE (Chicago Board of Options Exchange) grew quickly after the publication of the model, and Texas Instruments began selling calculators that had the equation built-in, marketing these calculators to options traders. Traders began quoting implied volatility to each other rather than the market price. Options are now among the most actively traded securities, and other forms of derivative securities have experienced exponential growth in recent years.