Use of Taguchi method for optimisation of process parameters of option pricing model

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Abstract: Options are generally utilised in the budgetary market and have the planned to bring a goliath rate of return and furthermore; they give various vital choices. In this paper, the optimal combination of options was evaluated for the first time utilising the Taguchi method. The Taguchi method analyses the impacts and relative significance of variables. The binomial option pricing model (BOPM) is used to estimate the values of options. The regression coefficients will give the connection between the elements and the reaction variable. The analysis of variance (ANOVA) and the analysis of mean (ANOM) are used for finding the best optimal combination among the parameters where the values of options are maximum and also it identifies which parameter impacts more on the option value. The Minitab programming is utilised for breaking down outcomes and the ANOVA and ANOM are used for optimising the result.

Keywords: binomial option pricing model; BOPM; Taguchi method; regression model; analysis of mean; ANOM; analysis of variance.

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1 Introduction

The world of financial market has experienced numerous subjective changes in the most recent four decades because of the exceptional development of derivatives. An option is a derivative instrument because the value of the right so conferred would depend on the price of the underlying asset at that time. Options are somewhat unique derivatives that confer a right to one of the parties to purchase or sell an underlying asset, while the other party is obligated to perform at the instance of the former. In other words, an option is a right, but not the obligation, to purchase or sell the underlying asset at a predetermined price (strike price) within a specified time period. An option to purchase is known as a call option and to sell is a put option. The holder of the option pays an amount (the premium) to the counterparty, called writer or seller, to induce him to confer the right.

The importance of trading an option is that it yields the higher return and includes less risk. It can be used to reduce the future loss (i.e., hedging), taking a view on the future movement of the underlying asset price, for arbitrage opportunities; strategies which can help in producing positive payoff for traders under various conditions of the market.

One of the main importance's of option is that for a small expense a trader can purchase a huge amount of underlying asset. Options are generally more volatile than their underlying instruments; therefore, investors get 'more bang for their buck' or more action. Option is the main technique or strategy where the holder of an option gets positive payoff not just when the market value of the underlying asset rises, but also when the market value of the underlying asset falls. With the assistance of options, the holder of an option can make a benefit from both bullish and bearish.

An option exchanging is a ventures technique that offers numerous decisions. One of the fundamental preferences is that exchanging option requires a holder to submit less capital to venture than straightforward exchanging. It is conceivable to make significantly more benefit, for much less cost and significantly less. As such, it is the potentially increases the noteworthy utilising a little measure of capital. It allows the holder to generate trading strategies with a limited loss, but with high probabilities of success and have complete control over the exposure to risk. It is possible for a trader to set a position so that he can make the only positive payoff. It gives much more profit for a given direction in the underlying asset price, and also it reduces the risk. On the other side, if the investor uses the option strategies in the wrong way; it can lead the trader to serious loss.

Good traders should have the patience to understand the essential mechanism of replicating the factors they trade. An option's price can be partial by various factors. In order to become up a strong option trader, it is important to comprehend the factors that impact the price of an option. Understanding these factors requires the learning of Greeks (Jose and Kanchan, 2017). Martinova (2014) who investigated the impact of factors on option fair value calculation and evaluate which factors are more significant, and can be chosen by option buyer or seller. The author changed one factor and kept other factors constant, in this way he found the impacts of factors on option value.

Determination of the option price is important for researchers, practitioners, and traders alike and it has been as one of the most challenging areas of derivatives. For traders, it is necessary to speculate and identify arbitrage opportunities. Various methodologies exist to value options. One of the most powerful, yet simple, approaches to value options is the binomial option pricing model (BOPM). There are five factors that impact the value of option; these the underlying asset price, interest rate, strike price, volatility and the time period. While creating strong option strategies, it is important for a trader of an option to think about the parameters that impact on the value of the options. In order to predict the accurate, one should know realistic information about input parameters. To know more and realistic information about the parameters (strike price K, the price of an underlying asset S_0, volatility σ, interest rate r, and time period t), a design of experiment (DOE) – Taguchi method is considered.

A DOE using the Taguchi orthogonal array approach can economically satisfy the needs of solving problem and products design optimisation projects. In this study, the Taguchi method is used for the first time to measure the impact of different factors on the option value with the help of BOPM. The impacts of factors – strike price K, the price of an underlying asset S_0, volatility σ, and time period t on European options were explored at constant interest rate r.

A DOE utilising the Taguchi method approach can financially fulfil the requirements of taking care of the issue and items plan streamlining ventures. By applying the Taguchi's strategy; analysts, specialists and researchers can lessen the time, assets and cash required for minimal test examination. It is a statistical technique for researching the connection between the components influencing a procedure and the result of that procedure and it gives the greatest sensible data with respect to the information elements of the reaction variable. To examine the best optimal combination where option value will get the maximum value, the Taguchi strategy is considered.

The effect of various factors on the option pricing values in a procedure can be analysed by utilising the orthogonal array approach (Taguchi strategy), regression analysis, analysis of mean (ANOM) and analysis of variance (ANOVA) and furthermore it found the best optimal combination where the estimation of the options are high. In this way, the goals of this examination are:

1 investigate which factor impacts more on the options

2 to find the best level combination of the options where the investor will get maximum return.

2 Literature review

Taguchi method – is an offline quality assurance technique used to accomplish the best performance of items and procedures. The fundamental motivation behind DOE is to compare the treatment in order to identify the best treatment or an alternative. The Taguchi method is being used in many fields such as glass manufacture to evaluate the levels required for various additives to optimise the physical properties of the glass, manufacture of car seat cushions, optimising the yield of a magnetic card reader, and it is used in various fields to investigate the effects of various input parameters on response variable such as:

Ketkar and Vaidya (2014) used the Taguchi method for signal to noise ratio, to select the quality and success of MBA program admission that depends on some factors such as 10th class marks, 12th class marks, and score at qualifying degree, work experience, entrance test, group exercise, and the personal interview. It investigated which factors effects more on the selection, the quality and success of MBA program admission. Hence the entrance test mark, group exercise score and personal interview score are considered to be useful for selection of MBA candidates

Chen and Ou (2011), in this study, the grey extreme learning machine (GELM) integrates grey relation analysis (GRA) and extreme learning machine with Taguchi method to support purchasing decision. GRA can sieve out the more influential factors from the raw data.

Babu et al. (2017) have done the investigation of various cutting parameters – feed rate (FR), cutting speed (CS) and depth of cut (DC) on tool life. The Taguchi L16 method and ANOVA was used in order to identify which parameter effects more on tool life. It was observed that the FR and DC have more significance on the tool vibration.

Khan et al. (2012) investigated a successful methodology for the improvement of an in-feed centreless cylindrical grinding of EN52 austenitic grade steel (DIN: X45CrSi93) with different execution qualities dependent on the grey relational analysis. To think about the impact of the whole space of the information factors, nine exploratory runs, in view of the Taguchi technique for L9 orthogonal array, were performed to decide the best factor level condition.

Celik and Karatepe (2007) used the Taguchi method to evaluate and forecast banking crises through neutral network model.

Viswanathan et al. (2017), this paper focuses around looking at the 'cutting zone temperature' while performing turning task on AZ91Mg alloy utilising established carbide devices. The regression show is produced by utilising the RSM methods dependent on trial results. It is uncovered that the cutting velocity (v) is the most predominant factor influencing cutting zone temperature.

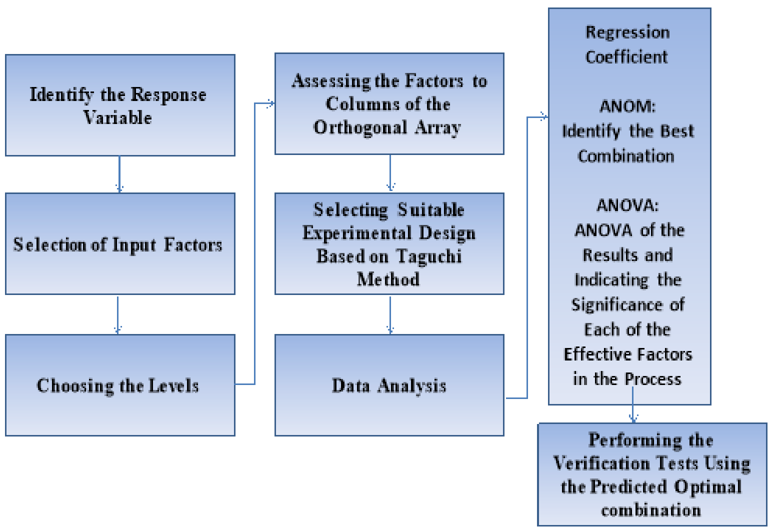
Dar et al. (2018) investigated the various parameters effects on the probability of default (PD). The parameters that affect the PD are: the value of the firm, debt, interest rate, volatility and time period. The Taguchi L27 method and ANOVA were used in order to verify which parameter impact more on PD. It was found that the volatility impact affects more on PD. Dar and Anuradha (2018a) have done the investigation on the European call option only at one time period. The parameters that affect the call option are an underlying asset, strike price, time period, interest rate and volatility. It was found that underlying asset impacts more on call option and also they described the optimal combination of a call option where the value of the call option is higher while using the Black Scholes formula for option pricing. Dar and Anuradha (2018b) have done the investigation on European Black Scholes formula for put option also at one time period. Parameters that affect the put option are an underlying asset, strike price, time period, interest rate and volatility. It was found that underlying asset impacts more on put option and also they described the optimal combination of put option where the value of an option is higher.

Related papers (Vankanti and Ganta, 2014; Kang and Hadfield, 2001; Kala and Chaubey, 2018; Singh et al., 2018; Auer, 2013).

3 Methodology

The most ideal approach to accomplish a high rate of speculation return is to put resources into options. It gives a financial investor the use that requirements to produce an exceptional payoff with a little speculation which can empower us to wind up shoestring tycoons. For creating the exceptional payoff on options, the speculators require enough information regarding the elements that impact on option valuing. In this examination, BOPM is utilised to appraise the reasonable price of options; the Taguchi strategy outline of test is utilised for exploratory setup; regression analysis, ANOM, and ANOVA are utilised to identify which factors impact more on option price value and also locate the optimal combination where the European call and put options are expanding. The Taguchi method is a DOE involves the following steps as shown in Figure 1.

Figure 1 Flow chart of Taguchi approach (see online version for colours)



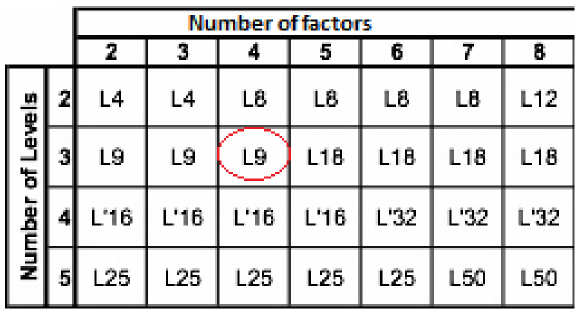
1 *Define the responsible/experimental value:* The output/response acquired from a trail of a test. This is likewise called ward factors. The responsible factors are the values of European call and European put options.

2 *Selection of input factors:* Input factors or variable which impacts or is associated with affecting the trademark being explored. All the information characteristics (input factors) which influence the input reaction of a framework are factors. Variables are shifted in the experiment. They can be controlled at settled levels. They can differ or set at levels of our advantage. The European call and put options rely upon a few factors, such factors are known as the information factors/input factors. The input factors in this study are: the underlying asset S_0 at time $t = 0$, the interest rate r, the strike price K, the time period T, and the volatility σ.

3 *Choosing the levels:* If the event that the responsible factors are a linear of the input factors, at that point the number of levels will be two. Be that as it may, if the responsible factors are not direct then one could go for 3, 4 or larger amounts.

4 *Choosing the orthogonal array:* 'Choosing the orthogonal array' depends on the chosen levels and the factors. The orthogonal array is a subset of the parameter space to represent a huge number of decision variables. Figure 2 shows the best way how to select the orthogonal array based on the chosen levels and the factors. In this study, the four parameters are varied at three levels and it shows that L9 – minimum 9 trails are enough to conduct the experiment.

Figure 2 Array selector (see online version for colours)



Number of Levels	Number of factors: 2	3	4	5	6	7	8
2	L4	L4	L8	L8	L8	L8	L12
3	L9	L9	L9	L18	L18	L18	L18
4	L'16	L'16	L'16	L'16	L'32	L'32	L'32
5	L25	L25	L25	L25	L25	L50	L50

The orthogonal array is a table of a matrix and subset of combinations of multiple factors at multiple levels. Its main aim is to find the effects of the input factors on the output with less number of experiments. The less number of experiments can be calculated by the following formula shown in equation (1):

$$N\ Taguchi = 1 + NF(NL - 1) \qquad (1)$$

where N – number of experiments are required, NF – number of parameters, and NL – number of levels. In this work, $NF = 4$ and $NL = 3$.

$$N\ Taguchi = 1 + 4(3 - 1) = 9$$

Therefore, at least nine experiments are required based on the orthogonal array for four factors at three levels as shown in Table 1. The following standard orthogonal arrays are commonly used for DOE.

Table 1 Standard orthogonal arrays

2-level arrays	L4, L8, L12, L16, L32
3-level arrays	L9, L18, L27
4-level arrays	L16, L32

In this work, the input factors are four at three levels. It would require a total of nine experiments to optimise the factors. It will provide us with enough information about what we required.

5 *Experimental value:* Simply substitutes the input in the experimental setup design and calculates the value of the call and put option. Table 2 shows the experimental setup for four factors at three levels as per Taguchi design.

Table 2 The levels of process parameters used Taguchi L9 orthogonal array

Experiment number	*Factors and experimental value*				
	A	*B*	*C*	*D*	*Experimental value*
1	A1	B1	C1	D1	E1
2	A1	B2	C2	D2	E2
3	A1	B3	C3	D3	E3
4	A2	B1	C2	D3	E4
5	A2	B2	C3	D1	E5
6	A2	B3	C1	D2	E6
7	A3	B1	C3	D2	E7
8	A3	B2	C1	D3	E8
9	A3	B3	C2	D1	E9

Where A, B, C and D are the input factors and the experimental value is the dependent/response variable that is given in the last column in Table 2. The A1 is the value of factor A at a level first, B1 is the value of factor B at a level first, so on. E1 denotes the experimental value of the first experiment.

6 *Analysis of response variables:* For analysing the data (the experimental results) several approaches are available. However, in this study the regression analysis, ANOM, and ANOVA are used to investigate the best optimal level where the response variable is maximum or minimum and also F-test is used for statistical significance.

When the data are analysed, the author must interpret the result from a practical point of view and it should be useful for the traders so that they can be benefited from the conclusion. The proposals include the levels for each one of the variables (the underlying asset S_0 at time $t = 0$, the interest rate r, the strike price K, the time period T, and the volatility σ – input factors examined) that optimises the output (reaction – estimation of options). Finally, it is also better to conduct tests (confirmation tests) using the chosen levels and the factors to validate the conclusion.

Table 3 The observed data of various factors

Levels	*Underlying asset price*	*Strike price*	*Volatility*	*Time period (months)*	*Option style*
1	10,744	10,800	15%	4	European
2	10,832	10,900	20%	8	European
3	10,987	11,000	25%	12	European

Notes: The interest rate is constant at 10% and it is also applied to estimate the implied volatility. The volatility is not known, so we assume some volatility at different levels to show our result

This investigation has been directed to test the impact of components and furthermore the rate commitment of each factor on options pricing. The information that is given in Table 3 is gathered from NSE at various dates.

4 European option

4.1 Basic

An option is a right, however not the commitment to offer or purchase an underlying asset at a predefined cost on a particular date. The options are characterised into two:

a call

b put option.

A call option is a privilege to purchase an underlying asset, while a put option is a privilege to sell an underlying asset. A financial specialist who purchases an option (call or put) is the option purchaser, and on the other hand, the speculator who offers an alternative is the option seller or writer. "Options are contracts in which the terms of the agreement are standardized and give the buyer the rights, but not the obligation, to buy or sell a particular underlying asset at a fixed price (strike price) for a specific period (expiry date)." The option markets give a system where a wide range of financial specialists can accomplish their specific venture objectives. An options financial specialist might search for long or short benefits, or they might look fence an existing underlying position. The best part about options is that a financial specialist can control underlying assets for a fraction amount of what it would sum you to get them inside and out and nearly get the equivalent. At the maturity date, there are just two potential outcomes either the cost of an underlying asset rise or fall. In the event of a call option, if the underlying asset value (*S*) has transcended the strike value, at that point the option merits the distinction between *t* the underlying asset price and strike price and if the underlying asset price has fallen beneath the strike value, it lapses useless. In this manner, the call option payoff is:

Mathematically at the maturity date, the payoff is:

$$Call\ payoff = \begin{cases} S_T - K, & \text{if } S_T \geq K \\ 0, & \text{if } S_T < K \end{cases}$$

$$CP = Max\left(S_T - K, 0\right) \tag{2}$$

A put works the opposite way. It gains value as the price of an underlying asset falls below the strike price. Thus, the call option payoff

Mathematically at the maturity date, the payoff is:

$$Put\ payoff = \begin{cases} K - S_T, & \text{if } S_T \leq K \\ 0, & \text{if } S_T > K \end{cases}$$

$$PP = Max\left(K - S_T, 0\right) \tag{3}$$

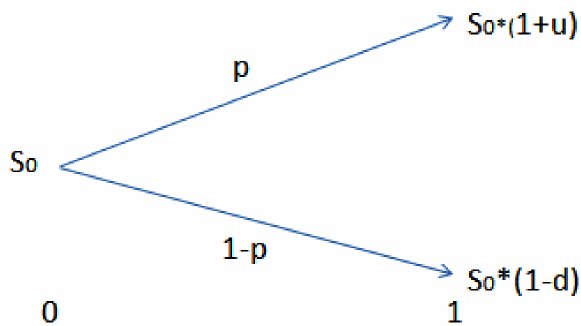
where S_T is the price of an underlying asset at the maturity date, *K* is the strike price.

4.2 Binomial option pricing model

To assess the option value at time $t = 0$, the BOPM is utilised in this paper. It is numerically basic and straightforward. It is a simplified representation of reality that utilises certain elements to create a yield, or result. A BOPM is a computational method that utilises the elements deciding the option prices as info and the yield is the hypothetical estimation of the options. It was first created by the three specialists to be specific Cox et al. in 1979. This model expects that the price of an underlying asset follows a binomial distribution which implies that there are just two conceivable outcomes of an underlying asset price, it is possible that it will rise or fall at the future date with certain probabilities. At each stage, the cost of benefit will climb or somewhere around particular variables '*u*' or '*d*' per step. In the event that the current price of an underlying asset is S_t, at that point in the following time frame the price of an underlying asset will either be $S_t * u$ (if the cost increments) or $S_t * d$ (if the value diminishes) with certain probability p (if the value rise) and $1 - p$ (if the value fall) has appeared in Figure 3.

The two possibilities for the underlying asset price at time $t = 1$ is shown in Figure 3.

Figure 3 One-period binomial model (see online version for colours)



The price of the underlying asset at time $t = 1$ is:

$$S_1 = \begin{cases} S_0 * (1+u), & \text{if the price moves up with probability } p \\ S_0 * (1-d), & \text{if the price moves down with probability } 1-p \end{cases}$$

where u is uptick percentage, $u > 1$ and d is downtick percentage, $d < 1$.

In order to avoid the arbitrage we must have an equality that is:

$$d < e^r < u \text{ or } p < 1$$

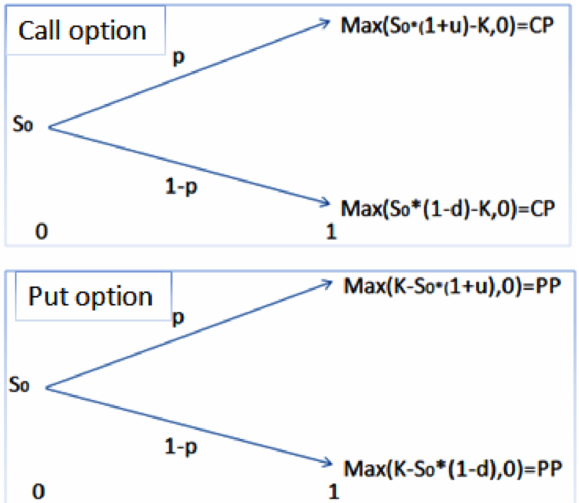
Let us assume that the call and put options exists for this underlying asset which expires at the end of one period. Suppose the strike price of a call option be K. At the end of the period the payoff's are shown in Figure 4.

The expected payoff at the end of the time period using the probabilities of up-state and down-state. From Figure 4, the expected value of payoff is

$$q * Max\lfloor S_0 * (1+d) - K, 0 \rfloor + (1-q) * Max\lfloor S_0 * (1-d) - K, 0 \rfloor$$
$$q * CP_u + (1-q) * CP_d \quad \text{(for call)}$$

$$q * Max\lfloor K - S_0 * (1+d), 0 \rfloor + (1-q) * Max\lfloor K - S_0 * (1-d), 0 \rfloor$$
$$q * PP_u + (1-q) * PP_d \quad \text{(for put)}$$

Figure 4 Payoff at the end of the period (see online version for colours)



Once we calculate the expected value of payoff, then we have to discount that expected value by the risk-free rate of interest r to get the arbitrage-free expected value of European call and put option at time $t = 0$. Use continuous discounting the expected value of the payoff. The theoretical fair value of the call and put options are:

- For call option

$$V_0 = e^{-rt}\left(q * CP_u + (1-q) * CP_d\right) \tag{4}$$

- For put option

$$V_0 = e^{-rt}\left(p * PP_u + (1-p) * PP_d\right) \tag{5}$$

The factor u and d are calculated by using the volatility and the time period.

$$u = e^{\sigma\sqrt{dt}}$$

$$d = e^{-\sigma\sqrt{dt}} = \frac{1}{u}$$

where dt is the time period of each step in the BOPM and the probability p can be defined as:

$$p = \frac{e^{rt} - d}{u - d}$$

For call option – CP_u is the payoff at the maturity date, when the price goes up with probability p and CP_d is the payoff at the maturity date, when the price goes down with probability $1 - p$ (Hull and Basu, 2016)

5 Taguchi method

The Taguchi method is a statistical technique and should be used in various fields to detect which factors have more significance on the response variable. A DOE is a systematic approach for solving the problems and it is a statistical method for investigating the relationship between the process inputs and the process outputs. It will provide the maximum and realistic information regarding the input parameters of the European options. Conducting a large number of experiments result may be heterogeneity and the experimental results tend to become inaccurate (more experimental error) (Krishnaiah and Shahabudeen, 2012). The Taguchi method is based on the additive assumption which implies that the main or individual effects of the factors on response variables are separable. Under this assumption, the effects of each factor can be linear, quadratic, or higher order, but the Taguchi model assumes that there exists no cross product effect or interactions among the individual factors.

One of the famous designs of experiment for fewer trials is a Taguchi method. It reduces time, cost and number of experiments. If we take into consideration the full factorial design – it contains all the possible combinations but the Taguchi method contains the minimal optimal set of experiments. For example, if we have four parameters at three levels, implementing the full factorial design we need 81 trials but as per the Taguchi method, we need a minimum nine trials as shown in Table 4.

Table 4 Full factorial design vs. Taguchi method

Orthogonal array	*Number of factors*	*Number of levels*	*Number of experiments as per Taguchi orthogonal array*	*Number of experiments as per full factorial design*
L4(2^3)	3	2	4	8
L8(2^7)	7	2	8	128
L12(2^{11})	11	2	12	2,048
L12(2^{15})	15	2	16	32,768
L9(3^4)	4	3	9	81
L16(4^5)	5	4	16	1,024

6 Result, analysis and discussion

To study the effect of four factors (the underlying asset S_0 at time $t = 0$, the strike price K, the time period T, and the volatility σ at constant interest rate) each at three levels using L9 orthogonal array experimental method. The results from three replications are given in Table 5. The factors that are shown in Table 3 are enough to estimate the fair price of the European call and put option by using the equations (4) and (5).

6.1 Regression analysis

In the experiment, if the response variable is linearly related to more than one independent variable, the relationship is modelled as multiple linear regressions. The test for the significance of regression is to determine whether there is a linear relationship between the response variable (value of call and put option) and the regression variables (underlying asset price, strike price, volatility and time period). A model that might describe the relationship is:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \ldots + a_nX_n + e \quad (6)$$

The parameters a_t, where t = 0, 1, 2, …, n are called regression coefficients, a_0 is also intercept and a_t, where t = 1, 2, …., n is also called the slope of the line.

Table 5 Taguchi L9 DOE with result

Experiment no.	*Factors/columns*				*Results*	
	*Underlying asset price S**	*Strike price K*	*Volatility σ*	*Time T*	*Call option value*	*Put option value*
1	10,744	10,800	0.15	0.333333	596.9357	298.8696
2	10,744	10,900	0.2	0.666667	1,095.837	548.8635
3	10,744	11,000	0.25	1	1,634.055	843.2666
4	10,832	10,800	0.2	1	1,564.232	504.4764
5	10,832	10,900	0.25	0.333333	906.9316	617.5871
6	10,832	11,000	0.15	0.666667	872.5259	331.1028
7	10,987	10,800	0.25	0.666667	1,543.647	660.1222
8	10,987	10,900	0.15	1	1,370.032	245.7599
9	10,987	11,000	0.2	0.333333	795.5771	447.9542

The appropriate null hypothesis

$$H_0 : a_1 = a_2 = \ldots = a_n = 0$$

And the alternative hypothesis

$$H_1 : a_t \neq 0, \forall t = 1, 2, \ldots, n$$

Rejection of null hypothesis implies that there is significant relation between the variables (response and the independent variable).

The ANOVA for the linear fitting is summarised in Table 6.

Table 6 ANOVA

		DOF	*Sum of square*	*Mean of square*	*F-value*	*P-value*
Call option value	Model	4	1.1713E6	292,826.8007	139.98868	1.50208E-4
	Error	4	8,367.156854	2,091.78921		
	Total	8	1.1796E6			
Put option value	Model	4	288,500.96453	292,826.8007	139.98868	1.50208E-4
	Error	4	7,530.54833	2,091.78921		
	Total	8	1.1796E6			

Result of Table 6: the P-value is approximately equal to zero at 95% confidence interval and it is less than the alpha (α = 0.05) providing strong evidence against the null hypothesis.

The quality of a regression model can be measured by the coefficient of determination. The adj. R-square is a value between 0 and 1. Generally if it is close to 1, the relationship between the response variable and the independent variables will be regarded as very strong and we can have high degree of confidence in our regression model.

Table 7 The regression coefficients of variables

	Call option value	*Call option value*
Number of trials	9	9
Degree of freedom (DOF)	4	4
Residual sum of squares	8367.15685	7530.54833
Adj. R-square	0.98581	0.94912

Table 7, shows that the adj. R-square of value of call and put option are 98.581% and 94.912% respectively. It shows that the fitted model is good fit of the data.

Table 8 The intercept and the slope of the variables value

Call option value		*Put option value*	
Factors	*Value*	*Factors*	*Value*
Intercept	863.09489	Intercept	1,418.605
Underlying asset price, St	0.152	Underlying asset price, St	–0.434
Strike price, K	–0.711	Strike price, K	0.265
Volatility, σ	4,150.465	Volatility, σ	4,150.811
Time period T	1,134.437	Time period T	114.345

The regression coefficients for call and put option are given in Table 8.

From Table 8, we also conclude that the strike price K effects inversely on the call option and the underlying asset price S_t on put options. Others factors are directly proposition to the option value.

6.2 Response total

Develop response totals table for factor effects, shown in Table 5. Table 9 is developed by adding the response values corresponding to each level of each factor. For example, level 1 totals of factor 'underlying asset price' is a sum of the observations from experiments 1, 2 and 3 from Table 5. That is,

$$S_1 = 596.93 + 1,095.83 + 1,634.05 = 3,326.828 \text{ for call option value}$$

$$S_1 = 298.87 + 548.86 + 843.26 = 1,691 \text{ for put option value}$$

Note that S_1 is the value of the underlying asset at level first.

Similarly, the level 2 totals of factor 'strike price' is the sum of response values from experiment 2, 5 and 8 from Table 5. That is,

$$K_2 = 1,095.83 + 906.93 + 1,370.032 = 3,372.801 \text{ for call option}$$

$K_2 = 548.86 + 617.58 + 245.76 = 1,412.211$ for put option

Table 9 Call option value (response) total for factor effects

Levels	*Factors*			
	Underlying asset price S_0	*Strike price K*	*Volatility σ*	*Time period T*
1	3,326.828	3,704.815	2,839.494	2,299.444
2	3,343.69	3,372.801	3,455.647	3,512.01
3	3,709.256	3,302.158	4,084.633	4,568.319

Table 10 Put option value (response) total for factor effects

Levels	*Factors*			
	Underlying asset price S_0	*Strike price K*	*Volatility σ*	*Time period T*
1	1,691	1,463.468	875.7324	1,364.411
2	1,453.166	1,412.211	1,501.294	1,540.088
3	1,353.836	1,622.324	2,120.976	1,593.503

6.3 Analysis of mean

The total value of call options is converted into the average response (value of options – call and put) and given in Tables 11 and 12. Each total (Tables 9 and 10) is divided by 3 to estimate the average response. In the average response, the absolute difference of the three levels at each factor is additionally recorded. The Delta indicates the effect of the factors on the response variable. These differences are ranked, starting with the highest difference as rank 1, the next highest difference as rank 2 and so on.

Table 11 Average value of call option and ranking of factor effects

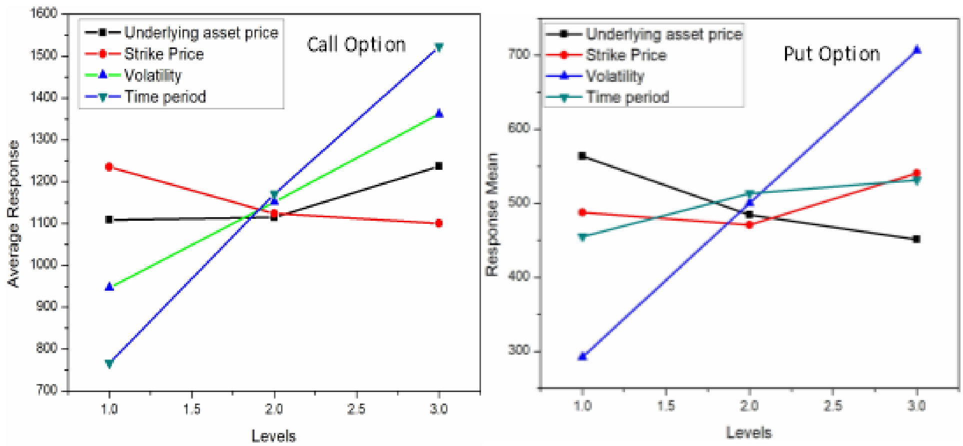
Levels	*Factors*			
	Underlying asset price S_0	*Strike price K*	*Volatility σ*	*Time period T*
1	1,108.943	*1,234.938*	946.4979	766.4815
2	1,114.563	1,124.267	1,151.882	1,170.67
3	*1,236.419*	1,100.719	*1,361.544*	*1,522.773*
Delta	127.4759	134.2189	415.0465	756.2916
Rank	4	3	2	1

Table 12 Average value of put option and ranking of factor effects

Levels	*Factors*			
	Underlying asset price S_0	*Strike price K*	*Volatility σ*	*Time period T*
1	*563.6666*	487.8227	291.9108	454.8036
2	484.3888	470.7369	500.4314	513.3628
3	451.2788	*540.7745*	*706.992*	*531.1676*
Delta	112.3878	70.03767	415.0812	76.364
Rank	2	4	1	3

From Tables 11 and 12, it is observed that factor 'time period' has the largest effect (rank 1) in case of call option and the volatility has highest effect in case of a put option. Figure 5 shows the value of a call and put with the average values. The slope of the time period and the volatility are higher in call and put option respectively. That indicates that the time period and the volatility has a higher effect on call and put option respectively.

Figure 5 Average response (see online version for colours)



6.4 *Predict the optimum combination*

The objective of this study is to maximise the response. For maximisation of response variables (call and put option values), the optimum condition is selected based on the higher mean value of each factor. According to Tables 11 and 12, the optimum condition is given by:

- For call option value (from Table 11)

  $S_3 * K_1 * \sigma_3 * t_3$

- For put option value (from Table 12)

  $S_1 * K_3 * \sigma_3 * t_3$

Both the combination provided the maximum value of the European call and put option value. Generally, all the factors will not contribute significantly.

The objective of this study is to maximise the value of the European option. For maximisation of European call and put option, the optimal condition is selected based on the higher average value of each parameter. From Figure 6(a) European call option for underlying asset price was found to be maximum for level 3, and its value is *1,236.419*, Figure 6(b) European call option for strike price was found to be maximum for level 1, and its value is *1,234.938*, Figure 6(c) European call option for volatility was found to be maximum for level 3, and its value is *1,361.544*, and Figure 6(d) European call option for time period was found to be maximum for level 3, and its value is *1,522.773*. According to Table 11, the optimal combination of a European call option is $S_3 * K_1 * \sigma_3 * T_3$. The selected combination provides the maximum value of the European call option. If we choose any possible combination from Table 3, we cannot find a single combination where we will get the maximum value of the European call option than $S_3 * K_1 * \sigma_3 * T_3$.

Figure 6 Effects of parameters on European call option (see online version for colours)

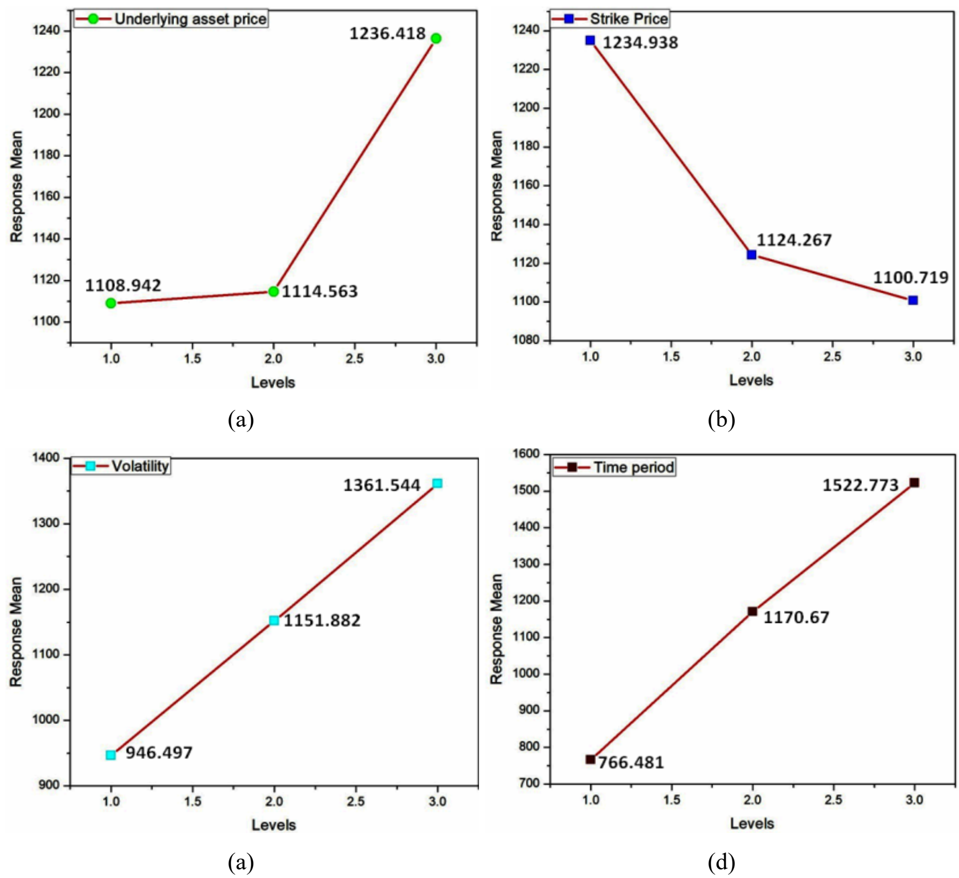


Figure 7 Effects of parameters on European put option (see online version for colours)

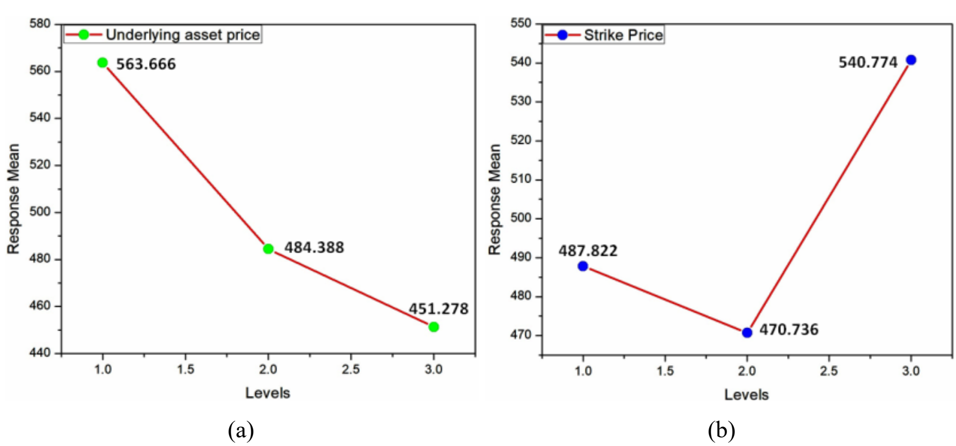
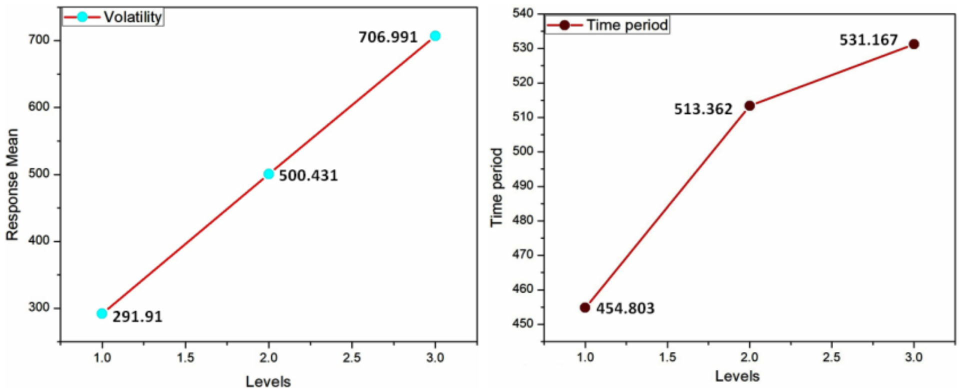


Figure 7 Effects of parameters on European put option (continued) (see online version for colours)



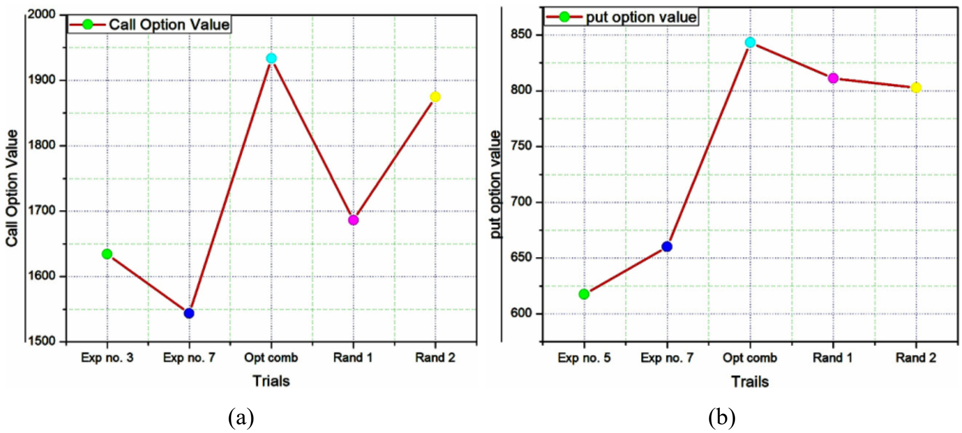
(c) (d)

From Figure 7(a) European put option for underlying asset price was found to be maximum for level 1, and its value is *563.6666*, Figure 7(b) European put option for strike price was found to be maximum for level 3, and its value is *540.7745*, Figure 7(c) European call option for volatility was found to be maximum for level 3, and its value is *706.992*, and Figure 7(d) European call option for time period was found to be maximum for level 3, and its value is *531.1676*. According to Table 12, the optimal combination of a European put option is $S_1 * K_3 * \sigma_3 * T_3$.

6.5 *Proof of the optimal combination*

The best combination has been determined for European call and put option as $S_3 * K_1 * \sigma_3 * T_3$ and $S_1 * K_3 * \sigma_3 * T_3$ respectively. In order to prove it, we selected some combinations from Table 5, i.e., experiment 3 ($S_1 * K_3 * \sigma_3 * T_3$), and experiment 7 ($S_3 * K_1 * \sigma_3 * T_3$) for comparison and experiment 7 ($S_3 * K_1 * \sigma_3 * T_2$) has largest output values. Further, other random experiments like ($S_3 * K_1 * \sigma_2 * T_3$), and ($S_3 * K_2 * \sigma_3 * T_3$) are elected for universality, the level combination of which is randomly chosen and it not included in the nine experiments that are given in Table 5. It is shown in Figure 8(a) that the optimal combination ($S_3 * K_1 * \sigma_3 * T_3 = 1{,}933.388$) provides us with the maximum value of the call option. For European put option again we selected some combinations from Table 5, i.e., experiment number 3 ($S_1 * K_3 * \sigma_3 * T_3$), experiment number 5 ($S_2 * K_2 * \sigma_3 * T_2$), and experiment number 7 ($S_3 * K_1 * \sigma_3 * T_2$) and the experiment number 3 has largest output value and also it is the best optimal combination also. Further, other random experiments like ($S_1 * K_2 * \sigma_3 * T_3$), and ($S_1 * K_1 * \sigma_3 * T_2$) are elected for universality, the level combination of which is randomly chosen and it not included in the nine experiments that are given in Table 5. It is shown in Figure 8(b) that the optimal combination ($S_1 * K_3 * \sigma_3 * T_3 = 843.2666$) gives us with the maximum value of the European put option.

Figure 8 Optimal combination (see online version for colours)



6.6 Data analysis using ANOVA

The ANOVA has been shown in Tables 12 and 13 with F ratio and the percentage contribution of each parameter on European call and put option respectively.

Table 13 The ANOVA result for European call option

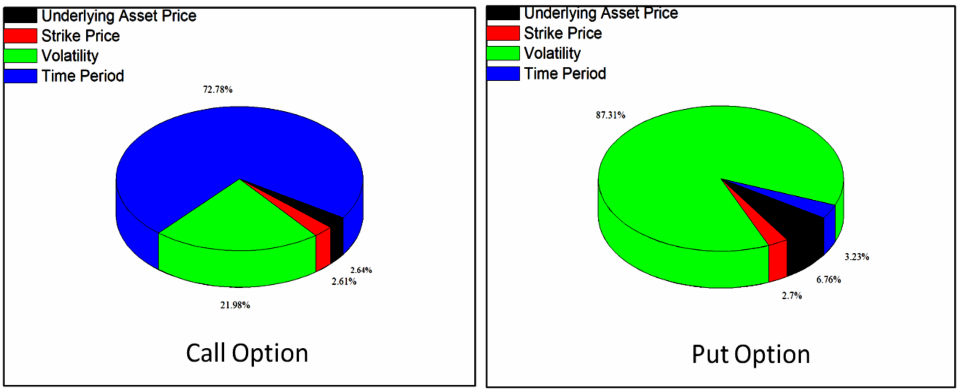
Sources of variation	*Sum of square*	*DOF*	*Mean sum of square*	*% cont*
Underlying asset price	31,130.427	2	15,565.21	2.638900048
Strike price	30,817.326	2	15,408.66	2.6123587
Volatility	258,404.59	2	12,9202.3	21.90473887
Time period	859,322.02	2	429,661	72.84400238
Error	3.725E-09	8	4.66E-10	
Total	117,9674.4			

Table 14 The ANOVA result for European put option

Sources of variation	*Sum of square*	*DOF*	*Mean sum of square*	*% cont*
Underlying asset price	20,012.26	2	10,006.13	6.76018
Strike price	8,001.094	2	4,000.547	2.702785
Volatility	258,440.5	2	12,9220.3	87.30169
Time period	9,577.649	2	4,788.825	3.235348
Error	0	2	0	
Total	296,031.5	8		

Figure 9(a) shows that the time period contribute more on call option, i.e., 72.84%% and the volatility gives 21.90% of its contribution. And the strike price and price of an underlying asset show 2.61% and 2.63% respectively of its contribution in the European call option. Figure 9(b) shows that the volatility contributes more on put option, i.e., 87.30% and the underlying asset gives 6.76% of its contribution. And the time period and strike price of show 3.23% and 2.70% respectively of its contribution in the European put option.

Figure 9 Contribution percentage of the European options (see online version for colours)



(a) (b)

7 Conclusions

The main criteria discussed in this paper concern the option parameters based on the Taguchi method orthogonal array design and the ANOM and ANOVA techniques were applied to determine the optimum level of each factor. The optimisation of options has crucial necessary to get a higher return from the market. In this study, an L9 Taguchi orthogonal method was applied to investigate the influences of factors – underlying asset, strike price, volatility and time period at the constant interest rate on the European options. Based on the L9 design, the most significant factors affecting the call and put options values a time period and volatility respectively. It was investigated that the strike price, and underlying asset price effects inversely to call and put option value respectively by regression coefficients. The ANOM utilised for investigating the best optimise value and it was found that $S_3 * K_1 * \sigma_3 * T_3$ and $S_1 * K_3 * \sigma_3 * T_3$ are the best combinations of call and put option values respectively. It also indicates that for call option – an investor needs high price of an underlying asset, the minimum value of strike price, maximum volatility and the maximum duration also and for put option – an investor needs the minimum price of an underlying asset, the maximum value of strike price, the maximum volatility and the maximum duration. ANOVA estimated the percentage contribution of each factor on options and it was found that time period and the volatility effects more on call and put option value by 72.84% and 87.30% respectively. The percentage contribution of each factor on the response variable will change if the dataset gets changes but the optimised value remains the same.

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