CHAPTER VIII
FINDINGS, CONCLUSION AND RECOMMENDATIONS

8.1 FINDINGS

The salient points of the findings of the entire research study are given in the following paragraphs.

8.1.1 SENSITIVITY

The sensitivity of the call option price to its variables and parameters are measured, observed and in depth dealt in the chapter III. The call option price is most sensitivity to stock price and strike price, almost at the same magnitude but in different direction. Call option price is related positively to stock price and negatively to strike price. Next, call option price is highly sensitive to the volatility of stock returns. The call option price is moderately sensitive to time of expiration (Life of Option) and least or insensitive to the risk - free - interest rate. The summary is tabulated in table no. 8.1.

TABLE 8.1
COMPARISON OF SENSITIVITY OF THE CALL OPTION PRICE TO THE VARIABLES

<table>
<thead>
<tr>
<th>Variables</th>
<th>% change in Variables</th>
<th>% change in Option Price</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHARE PRICE $S_0$</td>
<td>1.75</td>
<td>20.37</td>
<td>11.64</td>
</tr>
<tr>
<td>STRIKE PRICE $X$</td>
<td>1.63</td>
<td>-19.48</td>
<td>-11.95</td>
</tr>
<tr>
<td>VOLATILITY $\sigma$</td>
<td>74.63</td>
<td>64.08</td>
<td>0.86</td>
</tr>
<tr>
<td>LIFE $T$</td>
<td>44.74</td>
<td>27.43</td>
<td>0.61</td>
</tr>
<tr>
<td>RISK - FREE - INTEREST RATE $r$</td>
<td>155.56</td>
<td>6.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>
This information will be useful to the investors as they watch more sensitivity factors keenly than the others. Also, it helps them to forecast the price better according to the situation.

### 8.1.2 PREDICTABILITY

The BS model predicted the call option prices correctly in most of the cases. The percentage errors are calculated in each case; they are categorized into ± 5 percentage of errors and tabulated below.

**TABLE 8.2**

PERCENTAGE WISE PREDICTABILITY OF THE BS MODEL

<table>
<thead>
<tr>
<th>PREDICTABILITY</th>
<th>Error</th>
<th>Number of Negative Errors</th>
<th>Number of Positive Errors</th>
<th>Total Number of Errors</th>
<th>Cumu Total Number of Errors</th>
<th>% of Number of Errors</th>
<th>Cumu % of Number of Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% ± 5</td>
<td>7,781</td>
<td>10,524</td>
<td>18,305</td>
<td>18,305</td>
<td>19.08</td>
<td>19.08</td>
<td></td>
</tr>
<tr>
<td>90% ± 10</td>
<td>5,659</td>
<td>9,293</td>
<td>14,952</td>
<td>33,257</td>
<td>15.58</td>
<td>34.66</td>
<td></td>
</tr>
<tr>
<td>85% ± 15</td>
<td>4,420</td>
<td>7,530</td>
<td>11,950</td>
<td>45,207</td>
<td>12.45</td>
<td>47.11</td>
<td></td>
</tr>
<tr>
<td>80% ± 20</td>
<td>3,338</td>
<td>5,996</td>
<td>9,334</td>
<td>54,541</td>
<td>9.73</td>
<td>56.84</td>
<td></td>
</tr>
<tr>
<td>75% ± 25</td>
<td>2,599</td>
<td>5,052</td>
<td>7,651</td>
<td>62,192</td>
<td>7.97</td>
<td>64.81</td>
<td></td>
</tr>
<tr>
<td>70% ± 30</td>
<td>2,026</td>
<td>4,047</td>
<td>6,073</td>
<td>68,265</td>
<td>6.33</td>
<td>71.14</td>
<td></td>
</tr>
<tr>
<td>65% ± 35</td>
<td>1,739</td>
<td>3,261</td>
<td>5,000</td>
<td>73,265</td>
<td>5.21</td>
<td>76.35</td>
<td></td>
</tr>
<tr>
<td>60% ± 40</td>
<td>1,410</td>
<td>2,555</td>
<td>3,965</td>
<td>77,230</td>
<td>4.13</td>
<td>80.48</td>
<td></td>
</tr>
<tr>
<td>55% ± 45</td>
<td>1,119</td>
<td>2,125</td>
<td>3,244</td>
<td>80,474</td>
<td>3.38</td>
<td>83.87</td>
<td></td>
</tr>
<tr>
<td>50% ± 50</td>
<td>937</td>
<td>1,654</td>
<td>2,591</td>
<td>83,065</td>
<td>2.70</td>
<td>86.57</td>
<td></td>
</tr>
<tr>
<td>45% ± 55</td>
<td>794</td>
<td>1,330</td>
<td>2,124</td>
<td>85,189</td>
<td>2.21</td>
<td>88.78</td>
<td></td>
</tr>
<tr>
<td>40% ± 60</td>
<td>713</td>
<td>1,056</td>
<td>1,769</td>
<td>86,958</td>
<td>1.84</td>
<td>90.62</td>
<td></td>
</tr>
</tbody>
</table>

Cumu - Cumulative
Out of 95,956 options, the BS model has predicted the price with 95% accuracy in 18,305 options; that is 19.08%. 54,541 options that are 56.84% of the sample are predicted within 20 percentage error. The BS model has predicted more number of options within a reasonable accuracy and few have large errors. The same is depicted in the figure 8.1 below.

**FIGURE 8.1**
**PREDICTABILITY OF THE BS MODEL**

The higher errors are related to deep out-of-the-money options and deep in-the-money options as detailed in the chapters 4.5.1 and 4.5.2.

The Mean percentage errors vary from -3.51 to 7.10. That is, the BS model predicts the call option price with a minimum accuracy of 92.90% and a maximum accuracy of 96.49%; with mean 95.4%. But, considering the Mean absolute errors, predictability varies from 57% to 88%; mean being 76%. However, the predictability of most of the options is biased on higher side than the lower side. Middle fifty percentages of options are having the mean
predictability of 84.42%; the next 30 percentage of options are having the mean predictability of 76.29%. The predictability of the model in Indian Option Market is very good. In the research paper of Bakshi, Gurdip, Cao, Charles, and Chen, Zhiwu [10], “Empirical Performance of Alternative Option pricing Models” took a sample of 38,749 call options (S&P 500) for a period of June 1988 to May 1991, and estimated the Mean percentage pricing errors vary from 2.49% to -65.78% for the moneyness range of 1.06 to 0.94. That is the predictability varies from 34.22% to 97.51%. Fortune, Peter [53], in his findings inferred that the errors vary from 10 to 100 percentages. It may be concluded that the model's predictability in Indian Option Market is comparably better than the predictability of the model in overseas option markets as per the above research papers published abroad.

8.1.3 BIASES OF THE MODEL

All the variables and parameters of the model determinants are studied for the prediction biases, if any. The stock price and strike price are used together as moneyness and all the others are individually tested. The MAE and mean percentage errors are showing definite biases over change in moneyness, volatility and life of the options. The model does not exhibit any bias over risk - free - interest rate, which is the least sensitive factor of the model.

Our findings are in line with the biases that are explained in the papers of Geske, Robert and Roll, Richard in their paper [55], “The Black –Scholes call option pricing model is subject to systematic empirical biases. These biases have been documented with respect to the option’s exercise price, its time to expiration, and the underlying common stock’s volatility…”. Black, Fisher [23], MacBeth and Merville [94], Bakshi, Gurdip [10], and Rubinston [118] also confirmed the existence of the biases.
The predictability of the call option price by BS model is influenced by the moneyness, volatility range and life of the options as dealt in chapter IV. For the in-the-money options, the predictability is better than the out-of-the-money options. Likewise, the options having lesser life than 30 days got better predictability than the options with 31 to 60 days life.

Regarding volatility, the errors seem to be low at volatilities 0.20-0.30, 0.30-0.40, and 0.40-0.50. It can be seen that for very high volatility and very low volatility, the errors are higher. But the biases are not in the same direction in all the above cases. In Indian market, the BS model systematically underpriced deep OTM options and the deep ITM options. The near OTM options and ATM options are overpriced. Similarly, the model under-value:

- The options with volatility less than 0.40
- For options with moneyness less than 0.94 and more than 1.05
- The options with life less than 20 days.

The model more or less correctly predicts the options with moneyness 1.05-1.07 and overprices the remaining options. This is against the prediction of Black, Fisher [23] that the model systematically underpriced deep OTM options and overprices the deep ITM options. MacBeth and Merville [94] confirmed by the strike biases for the period 1975-1976, but found that it was the reverse of the biases reported by Black, Fisher [23].

But, these biases are systematic and can be used to rectify the errors also. For example, if the model under-prices the options of moneyness 1.02 - 1.04 by 4.50%; the investor can adjust the price accordingly and correct the error. Thus as far as the biases are systematic it can be used to predict the correct price by adjustments. However, a word of caution is that the systematic biases may change over different periods of observation like, recession period or boom period. Hence, the biases have to be determined periodically and can be used effectively.
8.1.4 RESIDUAL ANALYSIS

The residual analysis indicates that the residuals are mostly distributed near normal with respect to mean, median, mode, skewness etc, but kurtosis deviates highly from the normal distribution. That is residuals are not having a normal distribution but near to it.

The analysis of coefficients of correlation of the residuals with various variables and the parameters of the model indicates that stock price, strike price, time to expiration (life) and risk-free interest rate are insignificantly low and having no pattern. It may be inferred that the above four out of five factors of call option price are well defined in the model. When study the volatility of stock returns of the model, it is having a significant correlation with the residuals in the negative direction. In addition, almost, there is a pattern in residuals distribution. These findings show the finger against the volatility of stock returns, which might have some misspecification in the model. May be the way of prediction, the form / or structure of volatility may not be correct.

Thus, it may be concluded that volatility of stock returns is the only parameter of the model which is not satisfactorily / adequately incorporated in the model. The predictability of call option price by the BS model can be still improved if the volatility is adequately incorporated. In other words, improving the form and structure of the volatility in the model may improve the predictability.

The reason for inadequacy of volatility can be seen theoretically and practically. Theoretically, the number of days of stock prices considered for the calculations of the historical volatility is not fixed. More number of days will give low standard error as suggested by statistics. In opposite school of thought, very earlier price may not reflect the current situation and may distort the value. Thus finding the optimum number of days to calculate the volatility of stock returns is difficult and any wrong assumption may affect the predictability of the
model price. Moreover, practically, the volatility of stock returns depends on good / bad news about the company and investors psychology; which cannot be depicted from the historical prices.

8.1.5 VALIDITY OF ASSUMPTIONS OF THE MODEL

There are many assumptions developed during the derivation of the BS formula and the model. Out of which, seven assumptions are important as explained in chapters I and VI. Five of them are almost valid in Indian market and two of them are practically not validated, as assumed in the BS model. These are very important assumptions and logically will affect the call option price.

The stock price random walk concept has been tested with the technical analysis which is the very famous concept and technique used by most of the investors and broker-houses. Out of 36,889 payoffs, only 48.05% are positive and the remaining 51.95% times the signals resulted in loss (negative payoff). The second test of “Beating the Buy and Hold Policy” (B&H) found that technical analysis successfully predicted the future prices only 16.67% of the 504 sample periods are better than the Buy and Hold Policy. In 83.33% of the sample, the predictability of the technical analysis failed when compared the B&H policy. Thus the random walk theory assumed by the model is valid in Indian option market as empirically proved in the other part of the world.

As far as the lognormal distribution of the stock returns are concerned, in almost all companies, the mean and median are almost equal. The differences are very small. Mode is zero for all cases. Also, the skewnesses of the companies are almost near zero except for ACC, BHEL, CIPLA, SCI and WIPRO. The only major deviation is that the kurtosis is more than 3 in many cases. But, the Bowley’s Coefficients of Skewness (-0.04 to 0.12) and Pearson's skewness coefficients (-0.08 to 0.16) are insignificantly low. In view
of the above it may be concluded that though there are some variations, the log-returns of the stocks are almost have a normal distribution.

Regarding the assumption that option are European and pay no dividend, practically it is wrong as the stock options are American in nature and companies do pay dividend during the life of options. But, when the dividend paying stocks are eliminated from the sample and arbitrage opportunities are culled out. Thus in our study, these conditions are fulfilled.

The condition that continuous framework is practically wrong as the risk-free interest rates of MIBOR / MIBID etc are issued for the discrete periods only. The stocks and options are traded in discrete times. But, the data are converted into continuous form before applied in the BS formula. Thus theoretically and as well as samples are concerned, this condition is satisfied.

The conditions i) Continuous compounded risk-free-interest rate \( r \) and volatility \( \sigma \) of the log-returns on the stock are constant throughout the life of the options and ii) No taxation and transaction cost and stocks are perfectly divisible are practically wrong. For every day, different risk-free interest rates and different volatility are used as per the life period of the options and the company stock returns. Thus these assumptions are not correct and affect the call option price also.

8.1.6 IMPROVEMENT IN PREDICTABILITY

The suggested MIV method improved the predictability of the model in almost 64.23% of the sample size. In many cases, the improvements are up to 100% of the earlier method. The average of the MAE across various categories of moneyness has reduced to 0.19 from 0.28. (For various categories of moneyness from 0.83 to 1.20). One can keep in mind that the improvements are also found in the options that are very low traded (less than 5000). The improvements are broad based and felt across all moneyness, lives of options,
risk-free interest rate and volatility of the underlying stocks. The percentages of improvements are biased on the higher side than the lower side. The logic behind the use of MIV is also correct, meaningful, and appreciable. A clear view of the improvements is again shown below in the chart no. 8.2 for better continuity and understanding.

CHART 8.2

COMPARISON OF MEAN ABSOLUTE ERRORS RELATED TO THE OLD AND SUGGESTED METHODS.

The top three curves are the MAE belong to the original BS method using historic volatility and the lower three curves represent the MIV method errors. Errors are really reduced and the predictability improved in all ranges of moneyness. The improvements are also substantial. Thus MIV should be used
by the investors to predict the call option price using BS model to get more accurate prediction.

8.2 CONCLUSIONS

This research on call option price using BS formula covers vast period of five years and ten months with almost covering all the industries like Automobiles, Banks, Cement, Engineering, FMCG, IT, Oil, Pharmaceutical, Steel, Shipping, Telecom, Textiles etc. The sample size of 95,956 is one of the most extensive empirical studies reported in the literature till date. The data are tested for the suitability of theory and assumptions of the model, those which do not satisfy are eliminated.

This empirical study almost covered all the aspects of any empirical research, such as sensitivity of the model to its variables / parameters, predictability of the model, weakness of the model like biases, validity of the assumptions of the model, test of model adequacy through residual analysis and improvement of the model.

In developed markets, several authors have shown that the BS model is still the benchmark and working fine. In Indian option market also, results show satisfaction with the predictability of the model. The predictability have confirmed some systematic biases towards many of the parameters / variables as documented by the developer of the model Black, Fisher and other researchers abroad.

Deviations in some model assumptions in practice, with majority of the assumptions valid, do not affect the predictability of the model much. The study confirms the acceptability of the model in the market as in developed nations.
The model adequacy tests pass all the variables and parameters of the model for their conceptualization and incorporation except the volatility. This lead gives scope for the improvement of the model further.

The Mean Implied Volatility (MIV) can be used to improve the predictability of the model. Theoretical logics are also in support of the use of the same, as it has one volatility per day for all strikes and the actual information up to the previous day are impound in the prices of the stock as well in the volatility.

8.3 RECOMMENDATIONS

The BS model is the most recommended model for predicting the call option price under the theory of parsimony. Investors / academicians can use the MIV to improve the predictability of the call option price using BS model. The investors shall identify the biases during different economic scenario and can adjust the same in the prices as the biases are systematic but vary according to the time period. Excel “Goal seek” function can be used to find the implied volatility. Care should be taken that too extreme cases should not be considered to find the mean implied volatility. Some options may not have implied volatility and the same can be eliminated in finding the mean implied volatility as they normally belongs to deep OTM or deep ITM options.

The investors / academicians need not waste time in predicting the future stock prices using technical analysis etc, as it is proved futile. They may watch fundamentals of the economy, industry and company before decision making. The investors may concentrate on the volatility of the stock returns, leaving the less sensitive factors like life and RFR.

8.4 FURTHER SCOPE OF RESEARCH

The research can be extended to improve the MIV by finding the appropriate range of the moneyness of the options that are to be included in
finding the mean of implied volatilities. In our study, options related to moneyness ranging from 0.80 to 1.20 are considered to calculate the MIV. This range can be varied like 0.90 to 1.10 or 0.85 to 1.15 etc and check whether the predictability is improved further. In addition, one more research can be taken using the implied volatility of the particular moneyness can be used in the next day’s options with the corresponding moneyness. Also, the predictability and biases can be studied for various economic periods like normal, moderate boom, high boom, expected recession etc, and documented so that those percentage errors in these periods can be adjusted in future predictions of corresponding economic conditions.

A similar research can be taken for put options and may compare the same with this research on call options.