

## **LIST OF FIGURES**

Figure1.1. Five characteristics of innovations as per Rogers.....	23
Figure1.2. Five-step adoption process for innovative products .....	23
Figure1.3. The S-shaped curve of innovation diffusion.....	25
Figure1.4. Cyclical relation between digitalization of business models and product innovation .....	26
Figure1.5. Complementarity between the digital business models and the development of smart products.....	27
Figure2.1. The product life cycle of innovations and cumulative adoption in the S-shaped curve .....	42
Figure2.2. Framework of three popular innovation adoption theories .....	48
Figure2.3. Word Cloud of the keywords used in the research articles .....	49
Figure2.4. Series of Technology Generations .....	49
Figure2.5. Word Cloud formed from the key words and abstracts of the research articles .....	64
Figure3.1. Actual users of the Gen1 and Gen2 family along with the estimated/forecasted sales values .....	86
Figure3.2. Convex curve of $K(T)$ .....	92
Figure3.3. Inventory behavior of technology products in case of single generation product .....	96
Figure3.4. Inventory behavior of technology products in case of two successive generations .....	97
Figure3.5. Behavior of $EOQ_1$ and $TP_{Q_1,m}\%$ with the change in $m$ .....	100
Figure3.6. Influence of the launch of the second generation product on $EOQ_1$ .....	101
Figure3.7. Pictorial representation of the relationship between the EOQs and $\tau$ .....	102
Figure3.8. Impact of $\tau$ on the absolute profits and the profitability .....	103
Figure3.D.1. Influence of innovation and imitation coefficients of second generation on the demand of first generation product .....	107
Figure3.D.2. Influence of innovation coefficients over the cumulative adoption function .....	108
Figure3.D.3. Influence of imitation coefficient of any generation product over its cumulative adoption fraction .....	109
Figure3.D.4. Influence of innovation and imitation coefficients of second generation products on the optimal replenishment lot size of the first generation product .....	109
Figure4.1. Total Cost Curve for Case 1a When $PD \in (0, \tau]$ and $PD \in (0, T_1 - \tau]$ .....	119
Figure4.2. Total Cost Curve for Case 1b When $PD \in (0, \tau]$ and $PD \in (T_1 - \tau, \tau]$ .....	121
Figure4.3. Total Cost Curve for Case 2a When $PD \in (\tau, T_1)$ and $PD \in (T_1 - \tau, T_1)$ .....	122
Figure4.4. Total Cost Curve for Case 2b When $PD \in (\tau, T_1)$ and $PD \in (\tau, T_1 - \tau)$ .....	123
Figure4.5. Total Cost Curve for Case 3 When $PD \in (T_1, \infty)$ .....	123
Figure4.6. Time buckets into which product life cycle is divided in the single generation case .....	129
Figure4.7. Time buckets into which product life cycle is divided after the launch of the second generation product .....	130

Figure4.8. The trend of the optimal profit for varying levels of credit sensitivity .....	134
Figure4.E.1. Influence of credit period $PD_1$ on the adoption rate $f_1(t)$ .....	137
Figure4.E.2. Influence of credit period $PD_1$ on the cumulative adoption rate $F_1(t)$ .....	138
Figure4.G.1. Influence of the credit period of second product generation on the demand of the first generation product .....	139
Figure4.K.1. Service level determination for Profit Maximization in a capital constrained supply chain .....	141
Figure5.1. The behavior of the price of the technology products with the time elapsed after the launch for different values of annual % price drop “ $\gamma$ ” .....	148
Figure5.2. The P Model of inventory management before the launch of the second generation.....	150
Figure5.3. The P Model of inventory management in the $m^{th}$ planning horizon with $n$ replenishments before the launch of first-generation .....	151
Figure5.4. Steps performed in the optimization of inventory policies using a genetic algorithm .....	154
Figure5.A.1. Influence of diffusion rate of 2 <sup>nd</sup> generation product on phase-out timing of 1st generation.....	160
Figure5.D.1. Influence of price elasticity of demand on the diffusion pattern and revenues .....	163
Figure6.1. The P Model of inventory management before the launch of the second generation under two warehouse scenario .....	169
Figure6.2. The P Model of inventory management in the $m^{th}$ planning horizon with $n$ replenishments before the launch of the first generation .....	171
Figure6.A.1. Influence of increase in rent of second warehouse on the optimal replenishment frequency .....	176
Figure6.B.1. Influence of the coefficient of innovation and imitation on the optimal number of replenishments .....	177
Figure6.C.1. Influence of the rent of rented warehouse on the profitability of the first-generation product in the later stages of the product life cycle .....	177
Figure6.D.1. Influence of rent premium of the rented warehouse on the optimal service level .....	178
Figure6.E.1. Influence of the capacity deficit in the first warehouse on the optimal number of replenishments .....	179
Figure7.1. Visual Representation of the fuzzy number .....	187
Figure7.2. De-fuzzifying the Total Profit Function by Median Rule .....	188
Figure7.3. EOQ behaviour of the technology generations over the time horizons.....	191
Figure7.4. Revenues and profit behaviour of the technology generations over the time horizons ...	192
Figure7.D.1. Influence of the repeat purchase (of the advanced product by the existing adopters of older product) on economic lot size of the advanced product .....	197
Figure7.E.1. Influence of innovating and imitating tendency of the consumer on EOQ for technology products .....	197

## **LIST OF TABLES**

Table2.1. Demand rate function of some of the popular inventory studies .....	37
Table2.2. Research papers that have studied the consumer behaviour using different theories of innovation adoption .....	43
Table2.3. Diffusion theories used in the different research papers .....	46
Table2.4. History of research on modelling of innovation diffusion.....	52
Table2.5. Summary of research papers on Inventory Optimization for multi-item products .....	55
Table2.6. Analysis of existing literature on modelling for substitutable products in terms of objective, nature of substitution and Model used .....	65
Table2.7. The solution methodologies used in the research articles .....	69
Table3.1. Some of the important inventory researches in the area of non-constant demand or the demand substitution.....	81
Table3.2. Summary of the Estimation for the proposed model and Norton-Bass model .....	85
Table3.3. Forecasting ability of the Proposed Model and Norton and Bass Model (1971-1974) .....	86
Table3.4. Sensitivity analysis on $\tau$ .....	92
Table3.5. Sensitivity analysis on innovation and imitation coefficient of $i^{th}$ generation .....	93
Table3.6. Results of the Economic Order Quantity derived by running the model for single generation product .....	99
Table3.7. Results of the Economic Order Quantity derived by running the model for multiple generations .....	100
Table3.8. Sensitivity Analysis of the Proposed Inventory Model with different values of $\tau$ .....	101
Table4.1. Sensitivity analysis on $\tau$ .....	112
Table4.2. Sensitivity analysis on innovation coefficients.....	125
Table4.3. Sensitivity analysis on imitation coefficients .....	125
Table4.4. Demand patterns considered by the existing studies on credit linked demand.....	125
Table4.5. Optimal EOQ for the pooled logistics scenario .....	132
Table4.6. Influence on adoption of first generation product by changing the relative credit terms with the second generation product .....	133
Table4.7. Behaviour of total profit for different values of credit sensitivity .....	133
Table5.1. Tabular review of existing literature on multi-item inventory modelling under the price-dependent demand .....	143
Table5.2. Optimal $n_1$ and $n_2$ in pooled logistics determined by minimizing the sum of holding cost and carrying costs for each planning horizon .....	155
Table5.3. Total Revenue, Profits and Opportunity Loss for two generations scenario .....	155

Table5.4. Comparison of the replenishment dynamics: Joint vs Dis-joint for both the generations of products.....	156
Table5.5. Total Profit values $TP_{m',n_1n_2}^*$ for different values of yearly price drop % ( $\gamma$ ) with change in $\beta$ .....	157
Table5.6. Total Profit values $TP_{m',n_1n_2}^*$ for different planning horizons with different values of price sensitivity $\beta$ .....	157
Table6.1. Existing Literature on the inventory Multi-item Inventory Modelling under storage space constraints .....	165
Table6.2. Determination of Optimal number of replenishments for different planning horizons in single generation scenario .....	173
Table6.3. Determination of Optimal number of replenishments for different planning horizons in two generations scenario.....	174
Table7.1. Review of the studies on multi-item inventory modelling using fuzzy logic .....	181
Table7.2. Optimal EOQ under single generation scenario .....	191
Table7.3. Optimal EOQ post the launch of the second generation product with repeat purchase of second generation by the existing adopters of first generation .....	191
Table7.4. Optimal EOQ post the launch of the second generation product without repeat purchase of second generation by the existing adopters of first generation .....	192
Table7.5. Optimal EOQ with the increase in the innovation and imitation coefficients by 20%, with and without allowing the repeat purchase .....	192

## **LIST OF APPENDICES**

Appendix 3A: Nature of the cost components for Single Period Model .....	104
Appendix 3B: Theorem 3.1.....	106
Appendix 3C: Theorem 3.2.....	107
Appendix 3D: Theorem 3.3 .....	107
Appendix 3E: Theorem 3.4.....	109
Appendix 4A: Theorem 4.1 .....	135
Appendix 4B: Theorem 4.2 .....	136
Appendix 4C: Theorem 4.3 .....	136
Appendix 4D: Theorem 4.4 .....	136
Appendix 4E: Theorem 4.5 .....	136
Appendix 4F: Theorem 4.6 .....	138
Appendix 4G: Theorem 4.7 .....	138
Appendix 4H: Theorem 4.8 .....	139
Appendix 4I: Theorem 4.9 .....	139
Appendix 4J: Special Case 4.1.....	140
Appendix 4K: Special Case 4.2 .....	140
Appendix 5A: Theorem 5.1 .....	159
Appendix 5B: Theorem 5.2 .....	160
Appendix 5C: Theorem 5.3 .....	161
Appendix 5D: Theorem 5.4 .....	162
Appendix 6A: Theorem 6.1 .....	175
Appendix 6B: Theorem 6.2 .....	176
Appendix 6C: Theorem 6.3 .....	177
Appendix 6D: Theorem 6.4 .....	178
Appendix 6E: Theorem 6.5 .....	178
Cost Equations for Single generation case .....	194
Cost Equations for two generations case .....	195
Appendix 7C: Theorem 7.1 .....	196
Appendix 7D: Theorem 7.2 .....	196
Appendix 7E: Theorem 7.3 .....	197

## **Abbreviations**

EOQ: Economic Order Quantity

DOI: Diffusion Of Innovations

TAM: Technology Acceptance Model

NLP: Non Linear Programming

GA: Genetic Algorithm

PSO: Particle Swarm Optimization

DA: Differential Algorithms

MINLP: Mixed Integer Non-Linear Programming

GBM: Generalized Bass Model

NBM: Norton Bass Model

TOE Model: Technology, Organization and Environment Model

TPB: Theory of Planned Behaviour

UATUT: Unified Acceptance Theory