Conclusions and Directions for Future Research

In this thesis we have applied the techniques of operational research to model building in the field of marketing management and software engineering.

The thesis is divided into six chapters. The first chapter provides the motivations behind the work done in the thesis and briefly discusses some theoretical concepts and literature related to the work presented. A brief description of the work presented in rest of the chapters and scope of future research is being discussed below.

In chapter 2 we have proposed some IDMs based on SDE of \( \hat{t} \hat{e} \hat{o} \hat{s} \) type. Today’s world is an era of globalization. With the vigorous growth in the new technologies and rising needs of customer, the competition among the firms has grown manifolds and hence felt the requirement to further enhance the well known Bass model. One of the main drawbacks of Bass Model was that it considered market size to be fixed and only one purchase at a time, however, in reality the market size tends to increase with time and also consumers may buy the product more than once for their utility. Not everyone buys the product; there are always some consumers who leave the market without buying the product. It is these two classes of the market that our study was focused on by developing a more general mathematical model that is based on \( \hat{t} \hat{e} \hat{o} \hat{s} \) type of stochastic differential equation. The model has been achieved by using alternative formulation of the Bass model given by Kapur et.al. In later part of the chapter apart from the aforesaid concepts depicting adopters behavior, the concept of change-point due to various factors like change in marketing strategy and promotional campaigns etc has also been incorporated in the development of the model. Use of \( \hat{t} \hat{e} \hat{o} \hat{s} \) type stochastic differential equation for innovation-diffusion process puts the modeling on the larger canvas. The applicability and accuracy of the proposed models have been checked for new product sales data. It has been shown that stochastic differential equation based model performs comparatively better than Bass model. For further extensions in the
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proposed models, we can consider various other categories like personal, psychological, social that affect the consumer buying decision process. Here, we have taken the magnitude of the irregular fluctuation for adoption to be constant however it may change with time. This is also an important analysis required to be done in future.

Warranties serve as persuasive marketing tools: (i) promotional and (ii) protectional. As a promotional tool, warranties serve to promote the reliability and quality of a product with longer and better warranty terms implying a more reliable product. As a protectional tool, warranties provide assurance to consumers against defective products that fail to perform satisfactorily over the warranty period. This assurance reduces the risks associated with purchase of the product. This forms the basis of chapter 3. It has been divided in two sections. In the first section we have formulated an optimization problem which determines optimal adoption time and price for a product. The advantage of our formulated optimization problem is that it considers the effect of warranty cost while determining the maximum profit of the product. The other major stepping stone for the optimization problem is the two dimensional product sales model. Genetic Algorithm has been used to solve the problem. Numerical example is discussed to illustrate the solving of the optimization problem through GA. In future we can work on warranty cost with other distributions, apart from normal distribution spreading from zero to infinity. Also, working with different distribution for customer expectation and a product performance can be considered in future research. Further, for determining make accurate sales forecast for a new innovation we can consider more factors apart from time and price that affects a product's diffusion process.

The two proposed models in second section of chapter 3 presents a new outlook towards warranty and how manufacturer’s can use this commitment for their optimal growth. Producers often in the dilemma as in how to optimize their overall profit in the current scenarios of marketing with warranties can easily switch between the two models here and maintain both the marketability and profitability to the optimal level. The estimated results clearly indicate that the gradual shift from longer warranty period to a shorter duration warranty ensures major increase in the overall profit. In future we propose to use different distribution functions for modeling life time of a product within both the models.
Chapter 4 is divided into two sections. With the increase in population, purchasing power etc. the market size tends to increase over time. It is this fact that has been taken care of in first section of chapter 4. A diffusion model with increasing potential adopters has been proposed. It has also been illustrated how this different formulation itself incorporates the change in the adoption rate (change-point) because of changes in marketing strategies. In future, the study can be extended for more than one change-point. We also feel that the change point concept may assist in identifying future generation of adoption because of change in technology/ marketing strategies. Furthermore, an attempt can also be made to develop promotional effort dependent IDMs incorporating the change-point phenomenon.

The second section of this chapter contains a mathematical model for diffusion sales of successive generational technologies. The model decomposes the total sales into first time purchasers and repeat purchasers only. For high-technology products repeat purchasers constitute a substantial component of sales volume. Buyers from any of the generation product can become the potential purchasers of the other technology, thus the total number of potential repeat purchasers of any one generation is all the prior purchasers of other generation. And all the prior first time purchasers of second generation product can become the potential repeat purchasers of first generation product and vice versa. Apart from repeat purchasers there are some skippers, who might skip the potential generation and instead go for the other accessible generational product, that may give him the highest utility. Thus the behaviour of the two groups (first-time and repeat) of purchasers may be different and it is worthwhile to study the two sales components separately. The model has been used to formulate an optimization problem of entry of the newer generation product in the market under the objective of cost minimization. The model has been validated for Indian Television Industry. The results are very encouraging and the findings are consistent with the idea that attitudes of purchasers towards new generations change from the previous one and it is imperative to identify a trend. Furthermore, it is important to note that there is always a significant decline in competitiveness, usefulness, or value of a product which we call as obsolescence. Planned obsolescence or built-in obsolescence in industrial design is a policy of planning or designing a product with a limited useful life, so it will become obsolete, that is, unfashionable or no longer functional after a certain period of
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time. Planned obsolescence has potential benefits for a producer because to obtain continuing use of the product the consumer is under pressure to purchase again, whether from the same manufacturer (a replacement part or a newer model), or from a competitor which might also rely on planned obsolescence. The cost associated with this can be considered in the proposed model to study in future time.

From chapter 5, we take a route to software reliability. In the first section of chapter 5 an effort has been made to develop the model for successive software releases. Technological changes present terrible challenge for most business organizations especially in high technology product markets, as the development of new products are associated with high cost and risks. Software products in general face a severe competition in the market and therefore have to come up with frequent releases of their software by making some add-ons. In order to make sure that the multiple releases of software are beneficial to the developer, the testing of the upgraded system is of great importance. In this section we have proposed a multi-release model based on SDE of \( \text{it}^\circ \) type to capture the faults added at the time of introduction of the new product in the market. We put forward that when the testing of a newly developed code is in progress there is a chance that some faults of the previously released software may be found and removed. This helps us in removing more and more faults in the software and produces highly reliable software. The proposed model is estimated on a four release data set and gives reliable parameter estimates.

In the second section of this chapter we have developed the modeling that is based on all the assumption that have been used in Section 1 of this chapter along with the concept of severity of faults. The proposed model fits the data reasonably well. So the developer should do the positive and timely up-gradation by keeping sharp eye on user’s feedback and competitive market too. In future we propose to use different distribution functions for modeling different releases of the software.

A vital decision problem that the management encounters is to determine when to stop testing and release the software system to the user. Such a problem is known as “Software Release Time Problem”. If the release of the software is unduly delayed, the manufacturer (software developer) may suffer in terms of penalties and revenue loss,
while a premature release may cost heavily in terms of fixes (removals) to be done after release, which consequently might harm the manufacturer’s reputation. This is what chapter 6 is all about. In the first part we have proposed an SRGM for the successive release of the software using stochastic differential equations. While modeling the successive releases of the software we have assumed the interaction between the faults left in the just previous release and the new release. The stochastic process can be thought of as capturing uncertainties generated by stochastic fluctuations due to environmental conditions or so. The proposed multi release model is estimated on the real data set of four releases. Then a release planning problem is formulated and solved using Genetic algorithm which minimizes the expected software cost subject to removing a minimum desired proportion of faults from the new version that is to be brought into the market. The formulated release planning problem helps in determining both optimal release time and optimal resource consumption simultaneously. A numerical illustration is also given for the developed optimal release planning problem. The model can be extended by classifying the severity of faults, lying in the software. Some faults are easy to remove and some take more time to leave the system. This classification can be worked on in the future.

The second section deals with another release time problem for developers/testing team. On one hand, the software is expected to be tested in such a manner that it costs reasonable; on the other hand, failure intensity is also important because it is also an important aspect of software quality. The difficulty is that both of these factors are contradicting with each other. In order to make the judicious decision, the problem of determining the optimal time of software release has been formulated based on the concept of multi-attribute utility theory (MAUT) in terms of cost and failure intensity subject to the system constraints. The use of SRGMs to depict software reliability provides a statistical foundation to establish optimal release time for software testing. In future we can think of using some more attributes to decide on optimal release time of the software, keeping in mind the importance of attributes in deciding the release policy. In the present case the warranty cost can be added in the cost model of our decision model and that way we can further refine the decision model developed here.

Research in modeling and optimization in marketing and software reliability is not limited to the topic addressed in the thesis. Some of the emerging areas in the two fields
are based on the application of methods of soft computing such as neural networks, evolutionary computation, fuzzy logic etc in the model building and optimization. Incorporation of soft computing method is important to capture the existing uncertainties and problem complexities. Technology Management, Software Quality, are some of the recent areas of prime interest to the researchers in the field of marketing management and software engineering.

One interesting aspect of studying the two apparently unrelated fields of marketing and software reliability is the interdisciplinary nature of the subjects. In this thesis we have looked at various places where the fields join hands and enrich each other’s analysis. The successive generational model in marketing is structurally similar to the multi-release model in software reliability. Similarly various existing and emerging research in the two fields can be used to enhance the literature of both. For example, the cost optimization model developed in marketing sense has its roots from the basic cost model form software reliability. Increasing responsibilities of marketing managers and rapid evolution of information technology are opening various new dimensions of research in the two areas.