CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This thesis presents techniques of operational Research to model building and optimization in the field of Software Engineering. Globalization of economy, increase in quality standards, stronger competition on price and timely delivery of products/projects are deriving the management to have closer look on their decision making strategies, future prediction and analysis. This demands application of scientific procedures, processes, and approaches that is able to tradeoff between the conflicting objectives under system constraints. The concept of optimization as reflected in this thesis aids in analyzing these complex decisions. Using these optimization techniques one can approach a complex decision problem that involves the selection of values for number of interrelated variables and focus attention to the objective designed to quantify performance and measure the quality of the decision. Skill in modeling to capture the essential elements of a problem and good judgment in the interpretation of results is required to obtain meaningful conclusions.

Optimization of interest to software engineers in developing a component based software system includes optimal selection of components for the development of modular software system. This thesis has endeavored to make meaningful contribution to software reliability by formulating and solving optimization models for component selection in CBSD. For each of the proposed models the motivation behind it, the assumptions on which it is based, and data required for implementation are provided. Finally, the formulation of resulting model, the procedure for solving the model, and solution of the optimization models are shown. The models proposed in this thesis take into account many realistic factors like the issue of compatibility amongst the components of modules, selection of components using build-or-buy strategy, prevention of system failure by allowing mandatory redundancy in critical modules and uncertainty involved in decision making.

All said and done, there is always a scope of enhancement and expansion. Software reliability is a smoldering issue in all the industries that make a committed use of
software. With the advancement of technology, its continuous existence immensely depends upon frequent developments and innovations. This thesis has tried to make sincere efforts in applying optimization techniques to the area of component based software engineering. Notwithstanding the research done and contributions made, the conclusion touches some points of possibility of future research. This thesis is divided into five chapters. The first chapter provides the motivation behind the work done in the thesis and briefly discusses some theoretical concepts and literature related to the work presented. Now we briefly conclude the work presented in the rest of the chapters and discuss scope of future research.

In Chapter two optimization models for component selection of COTS based modular software system are developed. Large and complex software systems are increasingly being used at an alarming rate for various purposes. A component based software system is usually built up of multiple software modules such that each module is more manageable. Modules design is identified during the development process and integrated later to form a complete system. The modular design is even further sub divided into smaller components such that these small components can be developed independently and later linked to develop a full functionality. These components are known as COTS components and are available with the different vendors. Respective developers of the components provide information about their quality in terms of reliability, cost and execution time. In the first section of this chapter multi-objective optimization models are formulated for maximizing system reliability and minimizing the cost. The procedure is then developed to solve the multi-objective optimization model. Results are illustrated with the help of a numerical example. In the second section we have investigated a problem of component selection for a fault tolerant modular software system incorporating execution time. The execution time taken by the software to perform a function is important to a developer as well as user. Long execution time for performing a function may cause dissatisfaction and lead to low productivity of the system. The objective of the optimization models developed in this section is to select COTS components in such a way so that the reliability of the software system is maximum and the deviational execution time is minimum under the constraint of component selection and budget. The issue of compatibility of modules is also
discussed in both the sections as it is observed that some alternatives of a module may not be compatible with alternatives of other modules due to problems such as implementation, interfaces, and licensing. Numerical illustrations are provided to demonstrate the developed models.

The optimization problems for optimal component selection discussed in the above chapter has been formulated and solved under precise and well defined conditions. It is difficult to provide exact values of the parameters required for defining the objective functions and constraints as well as to describe the goals and constraints. This results in formulating the optimal component selection problem under fuzzy environment of optimization problems by crisp relations through equations due to various reasons. This resulted in formulating the optimal component selection problem under fuzzy environment. We have formulated optimization models for component selection problem in the presence of uncertainty, fuzzy set theory and fuzzy goal optimization procedures are discussed in Chapter 3 to quantify these uncertainties and solved the problems. The objective of reliability, cost and execution time are considered to be fuzzy numbers. Further fuzzy optimization technique is applied to solve the problem and illustrate the results numerically. This pioneering attempt has established the way of further research in the optimization of component selection under fuzzy environment. These are the few of the preliminary studies and much more work is required to be done in future in this area. Very few researchers have incorporated cohesion and coupling in the area of component selection. Coupling is about the measure of interactions among the software modules while cohesion is about the measure of interactions among software components which are within a software module. In future optimization models for component selection can be formulated in the development of fault tolerant software system by incorporating cohesion and coupling.

Chapter 4 focuses on “build-or-buy strategy” for component selection. The context and size of the software varies in different conditions, and is influenced by programming languages used and the system and application architectures. The trend is towards assembling software from existing software components developed using in-house resources and from the vendors supplied commercial-off-the-shelf (COTS)
components. In the previous two chapters we focused only on COTS based software development. Always using COTS components may not be profitable in terms of reliability, cost and availability. The organizations which are developing a software system may develop some of the components within the organization because they have the technology, resources and infrastructure. These components are known as in-house developed components. These components can be developed from the scratch or by reusing and modifying the existing components. Therefore, while developing a software, components can be both bought as commercial–off-the-shelf (COTS) components, and probably adapted to work in the software system, or they can be developed in-house. The optimization models build in this chapter aims at maximizing the system reliability and minimizing the overall cost under the various constraints of delivery time, testability, reliability, etc. Build-or-buy strategy is incorporated in the models. All the proposed models have been validated on the different actual data sets and the solution methodology is illustrated with a numerical example and a case study. The results obtained were encouraging. The results are shown with different delivery times. The results showed that when delivery time was small then all COTS components are selected which is obvious because in-house build components need sufficient time for testing. When delivery time was increased, then both COTS and in-house components are selected. The reliability in this case was improved significantly and the cost of acquiring components was reduced. Build-or-buy strategy has not yet incorporated in execution time-reliability model and can be done in future. In future the concept of cohesion and coupling can be incorporate to the models discussed above.

The problem of component selection for critical systems is discussed in Chapter -5. There are some modules in a system where failures can result in significant economic losses, physical damage or threats to human life. These modules are usually called critical modules. Therefore, there is a need for developing a system with a build in redundancy in the critical modules, so that if a particular component (alternative) in a module fails other one will take over and prevents the system from failure. The optimization models for component selection discussed in previous chapters are now formulated by incorporating build in redundancy in critical modules. Solution
methodology is illustrated with the numerical examples and a case study. The results are encouraging. In the solution set we can see that for all critical modules at least two components are selected. A lot of research can be done in this area as well.

Research in modeling and optimization in component based software engineering is not limited to the topics addressed in the thesis. Some of the emerging areas in this field are based on the application of methods of soft computing such as neural networks, evolutionary computation, heuristics and meta-heuristics, fuzzy logic and fuzzy set theory, etc. Incorporation of soft computing method is important to capture the existing uncertainties and problem complexities.

Moreover, we have considered only consensus recovery block (CRB) fault tolerant scheme for the selection of components. Further, other hybrid fault tolerance techniques can also be studied for optimal component selection of modular software system.

Rapid evolution of information technology and increasing responsibilities of software engineers are opening various new dimension of research in the area of CBSE. We can enrich the modeling optimization literature in several other ways, but the need is to find out these from the today’s environment and developing a logical and mathematical understanding.