Chapter 9

Closure

9.1 Conclusions

In this thesis, we study the queue-based service systems and machining system with distinct waiting variants. The present study mainly focuses on customer-oriented, server-oriented, and system-oriented performance prediction with their optimal and sensitivity analysis. From computational point of view, we have explored both steady-state and transient-state probabilities efficiently and employed nature-inspired optimization techniques. The current thesis is divided into three parts, namely, optimal analysis of the service system, sensitivity analysis of the service system, and the transient analysis of the machining system. In the first part, our primary intention is focused on the optimal interpretation of single and multiple-server service systems using several heuristic and metaheuristic optimization techniques. In the second part, we have performed the sensitivity analysis of the expected cost of the system for a finite controllable service system utilizing the working vacation and vacation interruption policies of the server. In the third part, we have executed the transient analysis of the queue-based service system and the fault-tolerant machining system.

In the thesis, several real-time models have been developed using a queueing-theoretic approach, which aids in the enhancement of performance, critical analysis, and forecasting of the service systems and fault-tolerant redundant repairable machining systems. The impact of several conflicting queueing terminologies such as customers' impatient, the vacation of the server, immediate feedback policy, optimal control of service system, et cetera in a finite capacity/population single/multi-server service system is examined critically. The assumptions for each model have been made as realistic as possible so that mathematical formulation can be done to evaluate the performance measures for the predictive purpose. To obtain queue-size distributions, either the Chapman-Kolmogorov differential-differential equations or identical matrix equations have been provided. Several quality performance measures of the system, such as expected length of the system, expected waiting time in

the system, the probability that the server is idle/busy/on vacation, the throughput of the system, and many more have been executed.

Additionally, some reliability characteristics such as system reliability, mean time-to-failure have been incorporated to observe the effect on the performance of the developed fault-tolerant machining systems.

Every event from customer's arrival to service, from vacation, breakdown to repair of server, waiting in the system, reluctance from the system, etc. in the service system and machining system involves the incurred cost. The cost optimization problem has been formulated to obtain the combined optimal values of the system design parameters. For optimal analysis, several heuristics and metaheuristic optimization techniques such as particle swarm optimization (PSO), cuckoo search (CS), bat algorithm (BA), and quasi-Newton method have been implemented to search for the global optimum of the expected cost of the system along with the optimal system design parameters. Several generations of the optimization algorithms have been demonstrated for the illustrative purpose, which validates the formulation of the governing model and cost optimization problem along with solution methodology.

Further, for the justification of the converging results, the statistical and comparative analysis between the findings of the optimization techniques has also been provided for some models. The parametric analysis, numerical simulation, and sensitivity analysis of several system performance measures have been accomplished in each model to visualize the impact of system parameters on the functioning and performance of the service system. Finally, several numerical examples have been accomplished to illustrate and achieve optimal solutions, and results are depicted in the form of different graphs and tables.

9.2 Specific Contributions

This thesis contributes to the various stochastic models based on several technical, managerial, and economic problems in service systems through the queueing-theoretic approach. Several queueing models comprise different arrival, server, and system-based queueing terminologies such as customers' impatient behavior, vacation policies of the server, arrival/service control policies in service systems, etc. have been dealt. Throughout the study, the following main findings as a specific contribution are delineated as follows

1. Queue-size distribution for transient or steady-state analysis of the studied service model is computed by employing efficient solution techniques such as the Runge-Kutta method and the matrix-analytic method.

2. Several system performance measures in closed-explicit expressions and vector-form representations are provided for the straightforward computation and comparative analysis of the performance of the service system.
3. Remarkable contribution of the thesis is the introduction of new terminology; emergency vacation in which the busy server can take a vacation in an emergent situation without completing the ongoing service of the waiting customer. In addition, we have included a recently developed terminology, unreliable service, and showed how it affects the performance of the service system.
4. It is observed that an extra effort for maintaining the high grade-of-service (GoS) is not always worthy, and hence, there is a requirement to incorporate the optimal service rates in the queue-based service systems. The developed queueing models would help the system analyst, decision-makers, and engineers to make a better choice for developing quality-of-service (QoS) and just-in-time (JIT) systems.
5. For the optimal service as per the expected cost and throughput of the system, optimal design parameter(s) have been determined. It has also been observed that the optimal design parameter(s) setup is important to reduce the expected total cost incurred in providing the service to the waiting customers.

9.3 Future Scope

The system designers, engineers, decision-makers, scholars, and scientists can use the design and modeling used and developed in studied models and their results for the industrial and management-based service systems. The queueing models developed in this study may further be extended utilizing other queueing terminologies such as bulk arrival/service, deterministic service, the retrial of the customer, the synchronous vacation of the server, and so on. In each developed queueing model, finding the explicit expressions of queue length and waiting time distribution is a difficult task. Therefore, demonstration of such explicit expressions of the system characteristics using several analytical solution techniques can also be assumed as the future scope of the present work. Moreover, the transient-state solutions can be established for such queueing models, and the concept of multi-server queues can be incorporated instead of a single server.

The models developed, the methodology used, and findings motivate research fellow for extension in the future to enrich the literature further.