STOCHASTIC ANALYSIS OF REPAIRABLE SYSTEMS OF NON-INDETERICAL UNITS OPERATING UNDER DIFFERENT WEATHER CONDITIONS

A Thesis

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SUMMARY OF THESIS

The importance of reliability theory has been felt in most of the branches of system engineering and applied sciences. It deals with the techniques of determining various performance measures of the system that may be subject to gradual deterioration. The technique of redundancy has been used as an effective strategy for improving performance of the systems. Therefore, the standby systems of identical units have attracted the attention of many applied probabilistics and reliability engineers for their applicability in their respective fields. But, in case of high cost of identical units, the non-identical unit (may be substandard unit) might be kept as spare in cold standby in order to maintain performance and efficiency of the systems for a reasonable time. On the other hand, weather conditions are considered as a major threat to the operation and repair activities of the systems. And, the impact of changing weather can be easily seen on the operation and repair activities of the system. Also, sometimes it is very difficult to keep the environmental conditions under control which may fluctuate due to changing climate and natural catastrophic. In view of these practical situations in mind the purpose of the present study is to analyze stochastic models for a repairable system of non-identical units operating under different weather conditions. The models have been developed by considering the aspects of no operation of the units in abnormal weather, no repair of the failed unit in abnormal weather, operation of the units in different weather conditions, priority for operation to main unit over the duplicate unit and priority for operation and repair to main unit over the duplicate unit. The expressions for various reliability measures have been derived in steady state by using semi-Markov process and regenerative point technique. The mean time to system failure (MTSF) and profit of the system models have been compared for arbitrary values of various parameters and costs.

The chapter wise summary of the work as follows:
Chapter 1
Introduction and Review of Literature

A brief introduction and review of literature are given in this chapter in order to introduce the reader to the problem. It covers the background and problem area of the research field. Some fundamental concepts such as system, system failure, repairable system, reliability, failure rate, repair rate, reliability models, system configurations, transforms and convolution, probability distributions, stochastic process, Markov process, Markov chain, Semi-Markov process, Regenerative process, reliability measures and profit analysis are discussed in brief to update about the knowledge of the subject. The organization of the thesis is given at the end of this chapter along with main findings of the study.

Chapter 2
Stochastic Analysis of a System of Non-Identical Units with no Operation and Repair in Abnormal Weather

In the present Chapter, a repairable system of two non-identical units – one is original (called main unit) and other is a substandard unit (called duplicate unit) has been analyzed stochastically in detail under two weather conditions – normal and abnormal. The environmental conditions when satisfied to the system correspond to normal weather; otherwise, it is supposed that the system is in abnormal weather. Initially, the system is operative with main unit and duplicate unit is kept a spare in cold standby. Both units have direct complete failure from normal mode. Each unit is capable of performing the same set of functions with different degree of reliability and desirability. There is a single server who visits the system immediately whenever needed to do repair of the failed unit in normal weather only. The operation and repair of the units are not allowed in abnormal weather as a precautionary measure to avoid excessive damage to the system. However, operation and repair of the units are as usual in normal weather. The units works as new after repair. The distributions of failure time of the units and change of weather conditions follow negative exponential
while that of repair times of the units are taken as arbitrary. All random variables are statistically independent. The switch devices and repairs are perfect. The expressions for various measures of system effectiveness such as transition probabilities, mean sojourn times, mean time to system failure (MTSF), availability, busy period of the server and profit function in steady state are derived using semi-Markov process and regenerative point technique. The numerical results giving particular values to the parameters and various costs are obtained for MTSF, availability and profit to depict their graphical behavior.

Chapter 3
Stochastic Analysis of a System of Non-Identical Units with Priority for Operation subject to no Operation and Repair in Abnormal Weather

This chapter has been designed to study a repairable system of two non-identical units – one is original (called main unit) and other is a substandard unit (called duplicate unit). Two weather conditions – normal and abnormal are considered. Initially, the main unit is operative and duplicate unit is kept as spare in cold standby. Priority is given to main unit for operation. The system is considered in upstate if either of the unit is functional. Both units have direct complete failure from normal mode. The set of activities performed by each unit are almost same but their performance measures are different. The operation and repair of the units are not allowed in abnormal weather. The single server attends the failed unit immediately in normal weather. The units works as new after repair. The failure times of units and time of change of weather conditions follow negative exponential distributions. And repair times of the units are arbitrarily distributed. All random variables are statistically independent. The switches are perfect. The system is observed at suitable regenerative epochs using semi-Markov process and regenerative point technique to derive the expressions for some reliability measure such as mean sojourn times, mean time to system failure (MTSF), steady state availability, busy period of the server, expected number of visits by the server and profit function. The numerical results for MTSF, availability and profit function have been obtained by considering particular values of the parameters and costs have been obtained to depict their behavior.
Chapter 4

Stochastic Analysis of a Repairable System of Non-Identical Units with Priority for Operation and Repair Subject to no Operation and Repair in abnormal Weather

In this chapter, we have developed a stochastic model of a repairable system of two non-identical units – one is original (called main unit) and other is substandard (called a duplicate unit) with the perception of priority for operation and repair activities to the main unit over the duplicate unit subject to two types of weather conditions-normal and abnormal. Initially, the main unit is operative and duplicate unit is kept as spare in cold standby. Each unit has direct complete failure from normal mode. Both units are capable of performing the system functions well with different degree of reliability and desirability. There is a single server who visits the system immediately whenever needed in normal weather conditions. The operation and repair activity of the system are not allowed in abnormal weather. After repair, each unit works as new. All random variables are statistically independent and uncorrelated. The switch devices are perfect. The failure times of the units and time of change of weather conditions follow negative exponential distributions. And, repair times of the units are arbitrarily distributed. Various reliability and performance measures such as transition probabilities, mean sojourn times, mean time to system failure (MTSF), steady state availability, busy period of the server, expected no of visits by the server and profit function are obtained using semi-Markov process and regenerative point technique. The graphical behavior of mean time to system failure (MTSF), availability and profit functions with respect to normal weather rate has also been examined for a particular case and fixed cost parameters. The profit function of the present chapter is compared with the profit function of chapter 2\textsuperscript{nd} and chapter 3\textsuperscript{rd}.
Chapter 5

Stochastic Analysis of a System of Non-Identical Units with no Repair in Abnormal Weather

The purpose of the present study is not only to strengthen the existing literature on reliability but also to know the variations in reliability and economic measures of a system of non-identical units operating in different weather conditions. To meet out this objective a stochastic model is developed under different set of assumptions on operation and repair policies. Initially, one original unit (called main unit) is operative and other substandard unit (called duplicate unit) is kept at spare in cold standby. Each unit has constant failure unit from normal mode. It is assumed that both units are capable of performing the same set of functions and activities but with different proficiencies. The system operates in two weather conditions - normal and abnormal. However, repair of the system is allowed only in normal weather by a server visits the system immediately as and when needed. The distribution of failure times of units and change of weather conditions are taken as negative exponential while that of repair times of the units follow arbitrary distributions. The units work as new after repair. All random variables are statistically independent. The semi-Markov and regenerative point technique are adopted to drive the expressions for the reliability measures such as mean time to system failure (MTSF), availability, busy period of the server, expected number of visits by the server and profit function. The results are analyzed through graphs for particular values of various parameters and costs. The mean time to system failure (MTSF) and profit of the present model are compared with that of model discussed in chapter 2nd.

Chapter 6

Stochastic Analysis of a System of Non-Identical Units with Priority for Operation Subject to no Repair in Abnormal Weather

The main object of this chapter is to develop a stochastic model for a system of non-identical units-one is original unit (called main unit) and the other is substandard unit (called duplicate unit).Initially, the original unit is operative and the substandard unit is kept as cold standby. Each unit has a constant failure rate from normal mode. A single server is provided immediately to carry out
repair activities in normal weather. The operation of the units is also allowed in abnormal weather. Priority is given to the operation of the main unit over the duplicate unit. The units works as new after repair. The distributions of the failure time of the units and change of weather conditions follow negative exponential whereas repair time of the units is arbitrarily distributed with different probability density functions. All random variables are statistically independent. The switch over is instantaneous and perfect. The expressions for some important reliability measures such as transition probabilities, mean sojourn times, mean time to system failure (MTSF), and availability, busy period of the server and profit function are derived in steady state using semi-Markov process and regenerative point technique. The variations in MTSF, availability and profit functions have been observed with respect to normal weather rate for arbitrary values of various parameters and costs. The MTSF and profit function of the present system model is compared with that of the models discussed in chapters 3rd and 5th.

Chapter 7
Stochastic Analysis of a System of Non-Identical Units with Priority for Operation and Repair Subject to no Repair Activities in Abnormal Weather

This chapter deals with a stochastic model for a system of non-identical units is developed by considering operation in abnormal weather and priority to operation and repair to the main unit over the duplicate unit. Initially, one original unit (called main unit) is operative while the other substandard unit (called duplicate unit) is taken as spare in cold standby. Each unit has direct complete failure from normal mode. A single server is available immediately to do repair of the unit in normal weather. The distributions of failure time of the units and time to change of weather conditions are taken as negative exponential while the distributions for repair time of the units are arbitrary with different probability density functions. All random variables are statistically independent. Repairs and switch devices are perfect. The expressions for some measures of system effectiveness such as transition probabilities, mean sojourn times, mean time to system failure (MTSF), availability, busy period of the server and profit function are derived in steady state. The graphs for MTSF, availability and profit have been drawn with respect to normal weather rate for arbitrary values of
various parameters and costs. The MTSF and profit of the present model is compared with the models discussed in chapters 4th, 5th and 6th.

**MAIN FINDINGS OF THE STUDY**

The stochastic modeling of a system of non-identical units operating under different weather conditions has been done by considering different operation and repair policies. The expressions for various reliability and economic measures of the system models have been derived in steady state using semi-Markov process and regenerative point technique. The results for performance measures of the system of vital significance have been obtained for arbitrary values of the parameters and costs.

The main findings of the study are follows:

- The mean time to system failure (MTSF) increases with the increase of abnormal weather rate and repair rates of the units, provided system is not allowed to operate in abnormal weather.
- The profit of the system models go on increasing as normal weather rate and repair rates increase.
- The system cannot be made more reliable and profitable to use by giving priority for operation to main unit over the duplicate unit provided system does not work in abnormal weather.
- The concept of priority for operation and repair to main unit over duplicate unit should be used when failure rate of the main unit is less than that of duplicate unit provided operation is not allowed in abnormal weather.
- The reliability measures keep on increasing with the increase of normal weather rate and repair rates of units provided operation of the system is allowed in abnormal weather also.
- The concept of priority for operation to main unit over the duplicate unit is not helpful in improving the reliability of the system if operation is allowed in abnormal weather.
- The system which operates in different weather conditions can be made more profitable by giving priority for operation and repair to main unit over duplicate unit rather than priority for operation only.