

# Chapter 3

## Methodology

### 3.1 Introduction

In this chapter, the methodology of fault analysis of the dragline system is described. The methodology of fault analysis of draglines is divided into three sections. The first section of the proposed methodology explains criticality of various components of dragline using FMECA. The second section of the methodology describes real-time fault analysis of the dragline using BN model. The third section describes the fault prediction of dragline subsystem using ANN. Finally, the summary of the proposed methodology is highlighted.

### 3.2 Development of Methodology

The methodology consists of three major parts as presented in Figure 3.1. The dragline working in the opencast coal mines in northern India is selected for the case study. Out of three draglines, the downtime of the drag system was 2044 hours is selected for the fault analysis. The first step is to collect the historical data of the fault and failure of the dragline from its maintenance worksheet from its commissioning on 9th May 2014 till 22nd September 2016. The critical subsystem of the dragline is analyzed based on the collected historical data. The FMECA methodology as described in the sub-section 3.2.1, helped in identifying the most critical components of dragline using RPN. The real-time fault analysis of the drag system is described in sub-section 3.2.2. The fault prediction of the drag system is described in sub-section 3.2.3.

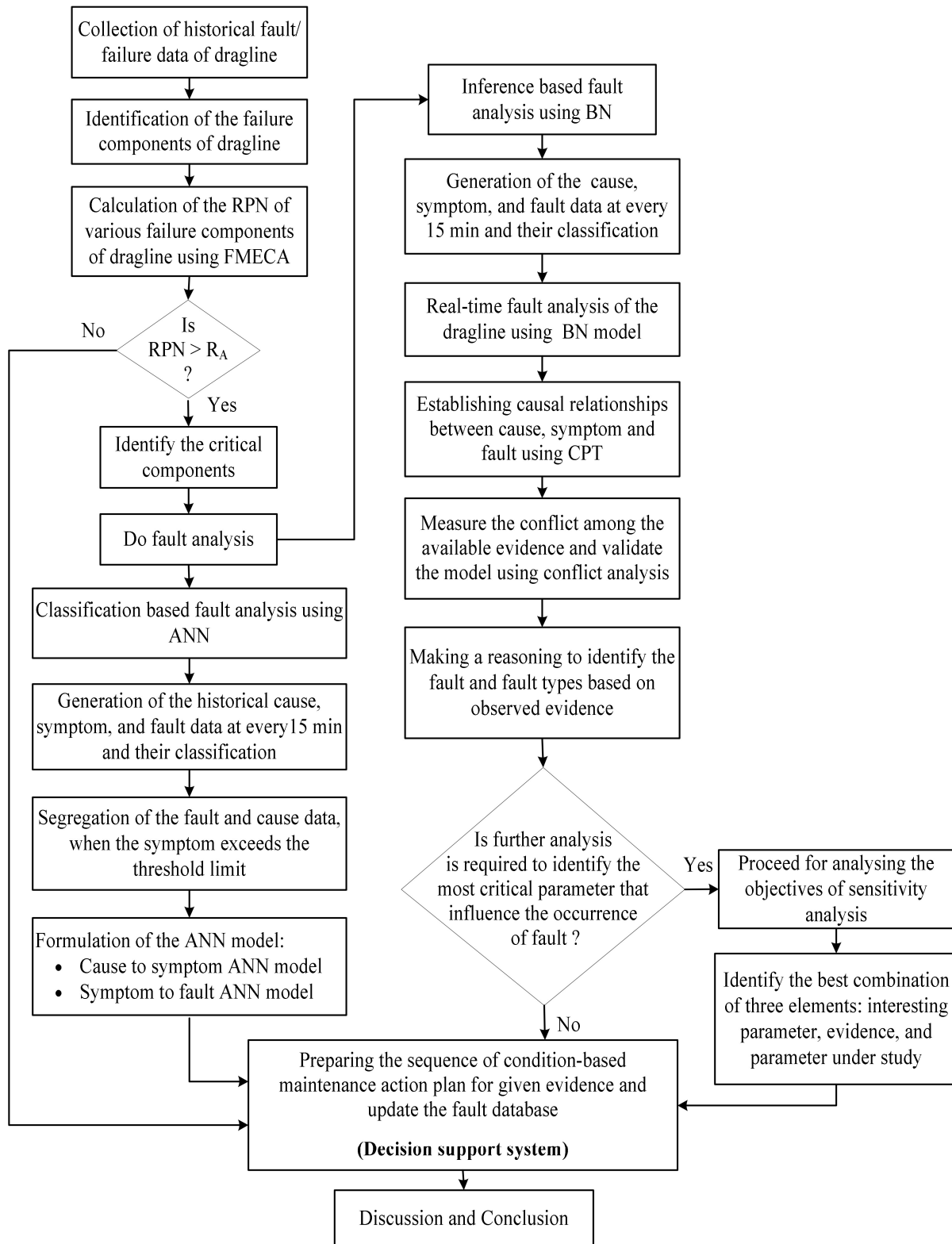


Figure 3.1 Flowchart of the research work

### **3.2.1 Criticality analysis of dragline components using failure mode, effects and criticality analysis**

The FMECA is used for systematic evaluation of the failure occurrence, safety and detectability of potential failure modes and to fully understand the causes and their effects on the performance of the system [252]. In this study, both mechanical and functional failure of components of the dragline has been considered. Mechanical failure mechanisms mainly occur due to fatigue (constant cycle of stress wears out material), corrosion (steady loss of material over time leads to failure), or wear (material loss and deformation). Each produces different types of fracture and failure. These failures occur gradually leading to hardware/mechanical failure and sometimes responsible for the functional failure of the system.

FMECA is used to tabulate the list of various components and their possible failure under their operational conditions. This study is capable of identifying the possible failure modes of each component present in the system and their effects of failure on the overall performance of the system by estimating the RPN. The risk assessment of various components consists of mainly two stages: (i) risk estimation, and (ii) risk evaluation [253], [254]. To calculate the risk value (RPN) of various components, three parameters such as frequency of occurrences, magnitude of consequences (production loss, and defect of the components) are considered. The flow chart of criticality analysis of dragline using FMECA to estimate the risk is shown in Figure 3.2 [78], [255].

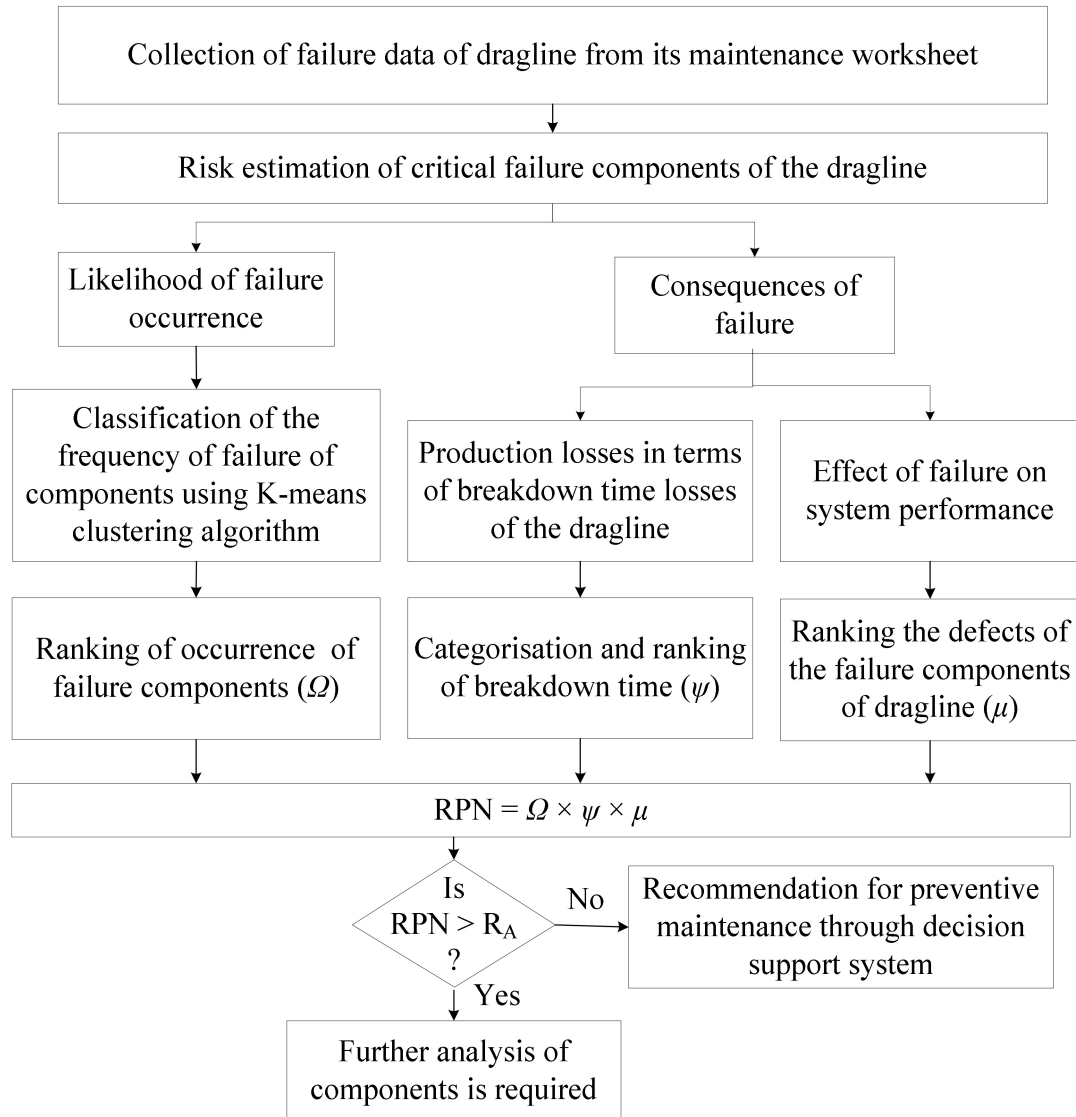


Figure 3.2. Flow chart of criticality analysis and assessment of RPN of dragline

The FMECA of the components of the dragline is proposed to estimate the risk of the failed components. The risk of the components is associated with the likelihood of occurrence of failure ( $\Omega$ ), loss of production in terms of breakdown time losses ( $\Psi$ ), failure effect that degrades the performance of the system in terms of occurrence of a defect in the component ( $\mu$ ). Risk estimation has been carried out for the dragline components to estimate the risk priority number is given in Eq (3.1):

$$\text{RPN} = \Omega \times \Psi \times \mu \quad (3.1)$$

The estimation of  $\Omega$ ,  $\Psi$ , and  $\mu$  are described in detail in sub-sections 4.3.1 and 4.3.2. The estimated RPN score can be analyzed based on the acceptable risk ( $R_A$ ) limit.

### 3.2.2 BN based fault analysis of the dragline system

For real-time fault analysis of the dragline system, a BN model was constructed. The causal relationship between cause, symptom, and fault is established using *Netica software* [256]. The CPT of BN model is updated when new evidences are observed. The conflict analysis is used to measure the conflict value among the available evidence as well as to validate the model. The fault inference of the BN model uses to make reasoning to identify the fault type (no fault, catastrophic fault, degraded fault, and intermittent fault) based on the prior probability, likelihood, and posterior probability of interesting fault for given evidence. In this study, one-way sensitivity analysis is used to know the root causes and symptoms that mostly influence the targeted fault, which must be quantified based on the given evidence. The accuracy of the BN model is calculated in terms of error using validation dataset for the most influencing parameter of interesting fault. The three-axiom-based sensitivity analysis approach proposed by Jones et al. [257] is also used to partially validate the BN model. The details of data collection and classification are presented in Chapter 4. The fault analysis of the drag system using the BN model and its validation is presented in Chapter 5.

### **3.2.3 ANN based fault analysis of the dragline system**

The cause, symptom and fault data is collected when the symptoms exceeded predefined threshold limit and it is used to predict the fault by constructing the ANN model using SPSS software [258]. In this study, two ANN models are used to predict the occurrence of the fault. The first ANN model is based on cause and symptom, used to predict the symptom to prioritize the sequence of responsible root cause to avoid the occurrence of the symptom as well as fault. The second ANN model is based on symptom and fault and is used to predict the possible occurrence of faults to avoid catastrophic failure in the dragline system whenever the symptom exceeds the threshold limit. The detailed description of fault prediction of drag system using ANN model is presented in Chapter 6.

## **3.3 Summary**

The method of proposed research work has been described that consists of three sections. The first section of the proposed methodology explained the identification of criticality of failure components of dragline to prioritize the preventive maintenance policy using FMECA by estimating the RPN. The second section presented the fault analysis using BN model to identify the fault, and detect the conflict among the observed evidences. The third section presented the fault analysis using ANN to predict the fault and responsible root causes based on the observed evidence.