

# Bayesian Analysis for Assessing Risks of Rotating Equipment and Its Financial Loss

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**Abstract.** The petrochemical industry is equipped with major and rotating equipment, such as storage tanks and pumps, to produce the required outputs. The equipment could pose a high level of risks should the organization failed to provide control and mitigation measures. Risk analysis is a conventional and practical technique in identifying hazards and assessing risks associated with equipment. The risk analysis can be integrated with the Bayes's theorem to assess risks of major and rotating equipment. Therefore, this paper presents the use of Bayesian analysis for assessing risks of rotating equipment and its financial loss, specifically in the petrochemical industry. The study begins with developing a cause-and-effect relationship using a Bayesian network. The probability of failure of equipment and its financial loss can be analyzed based on the Bayesian network. The cause-and-effect relationship could also reveal human factors contributing to the probability of failure of equipment. This paper focuses on an accident involving pumps during maintenance activity in the petrochemical plant. The human factors issues contributing to the accident and the financial loss are inadequate procedures and poor work processes.

## 1. Introduction

Organizations or companies make decisions based on the risk analysis. In engineering field, risk analysis could help the organization or management to develop or design the engineering system. Understanding the risks and the process for analysing the risks have a significant impact to the outcome of engineering design.

The process on identifying hazards and risk factors that have potential to cause harm is known by risk assessment. But, the term not only for this. Risk assessment also focusing on analyse and evaluate the risk associated with the hazard. Find appropriate ways to eliminate the hazard, and to control the risk if the hazard cannot be eliminated is another term where risk assessment take part [1].

Risk assessment have two different perspective. Engineering perspective and insurance company perspective. Engineering here refers to the engineer and all equipment that involve in a chemical process plant. All the hazard material and dangerous equipment will be the main consideration for the risk assessment due to the high potential for causing harm. Risk assessment on engineering perspective focusing on risk management before, during, and after the events of hazards.

Insurance company focus on relationship between risk assessment and financial. Financial for insurance company related to payment for equipment loss and for injury worker. Because of this,



insurance company will consider about risk assessment. Because it can help them to manage their financial and to reduce payment for the injury of the worker and equipment loss [2], [3].

Risk assessment in the insurance company is the important to be consider by the company. Since the insurance companies are selling what numerous people consider to be a risk mitigation. The insurance companies find an assortment of risk they have to mitigate.

### *1.1. Risk assessment for engineering and insurance companies*

The petrochemical industry and the insurance company may have different perspectives on risks. The petrochemical industry focuses on the consideration of the risk assessment about harm factors and hazardous materials [4], [5]. They concern the safety of workers, safe working with equipment, and preventing workers from accidents [6]. This perspective also considering the procedure on how to treat the injury when it already happened. With the number of equipment and hazardous materials on a plant, the probability of getting injured during work is high. The risk assessment also helps the engineer to control the maintenance of the equipment. The petrochemical industry can prepare for scheduled maintenance and its costs when they know the failure probability of the equipment.

The risk assessment helps insurance companies to balance the profitability with the probability of injury sustained by the workers, as well as the probability of equipment failure. For well-established insurance company companies, the risks around investment and asset or liability matching far exceed the risk of morbidity or mortality. Risk is made up of two parts; the probability of the equipment going wrong and the negative consequences.

The insurance company focuses on getting benefit from the risk assessment. If the company has a lower number of accidents, the insurance company gets the benefit as the engineering company keeps paying for the insurance following the contract. The insurance company should understand the workplace and the equipment in the industry to provide a suitable coverage premium.

In case the accident happened, the insurance coverage does not state either on the premium or the deal. Such situation could cause both the engineering and insurance companies to blame each other. The insurance company may not pay for the accident cost because it not stated on the premium. On the other hand, the engineering company asks for responsibility because they paid a certain amount of money for insurance. The insurance company does not cover equipment with a high probability of failure or errors. Thus, the workers need to work carefully with the equipment, and they need to get full knowledge about the procedure to operate the equipment.

### *1.2. Objectives*

The objectives of research work are as follows:

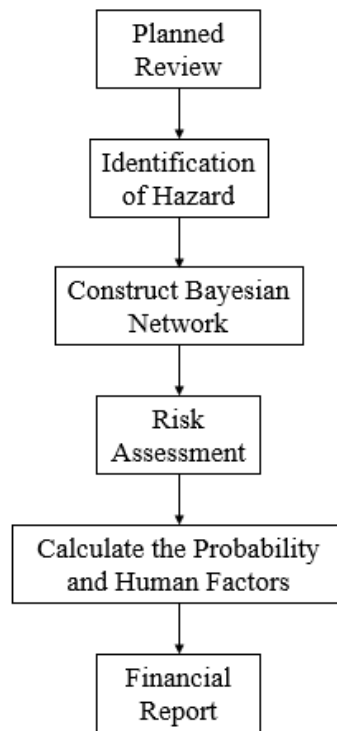
- i) To identify the presence of human factors during the maintenance activities of rotating equipment.
- ii) To develop cause-and-effect relationship that can contribute to financial loss to insurance company.
- iii) To analyse risk of equipment considering the financial loss.

## **2. Methodology**

The study focuses on the centrifugal pump, which is commonly used the petrochemical industry. Centrifugal pumps handle most types of liquid and design in two configurations; vertical and horizontal.

### *2.1. Risk Analysis Sequences*

In order to achieve the objectives of research, a method have been used to get the cause-and-effects relationship for the risk assessment [7]. The method is known as the Bayesian Network. And there is a flow as shown in Figure 1 that need to follow to complete the research.



**Figure 1.** The sequences of risk analysis.

### 2.2. Bayesian Network

Bayesian Network is a method to combine prior information about a parameter with information, for this research is risk assessment from sample to guide the statistical process. Bayesian Network are a type of Probabilistic Graphical Model that can be used to make models from data/or expert opinion [8]. Bayesian Network expect to demonstrate prohibitive dependence, and along in this way causation, by addressing unforeseen dependence by edges in a planned outline. Through these connections, one can successfully lead inference on the unpredictable factors in the diagram utilizing factors.

### 2.3. Four Major Analytics Disciplines

A Bayesian Network represent the simple probabilistic relationship between a set of variables, their contingent conditions, and it gives a minimal representation of a joint probability distribution.

In term of probability distribution, Bayesian Network can be categorized into four major analytics disciplines as shown in Figure 2. Descriptive analytics, diagnostic analytics, predictive analytics, and perspective analytics

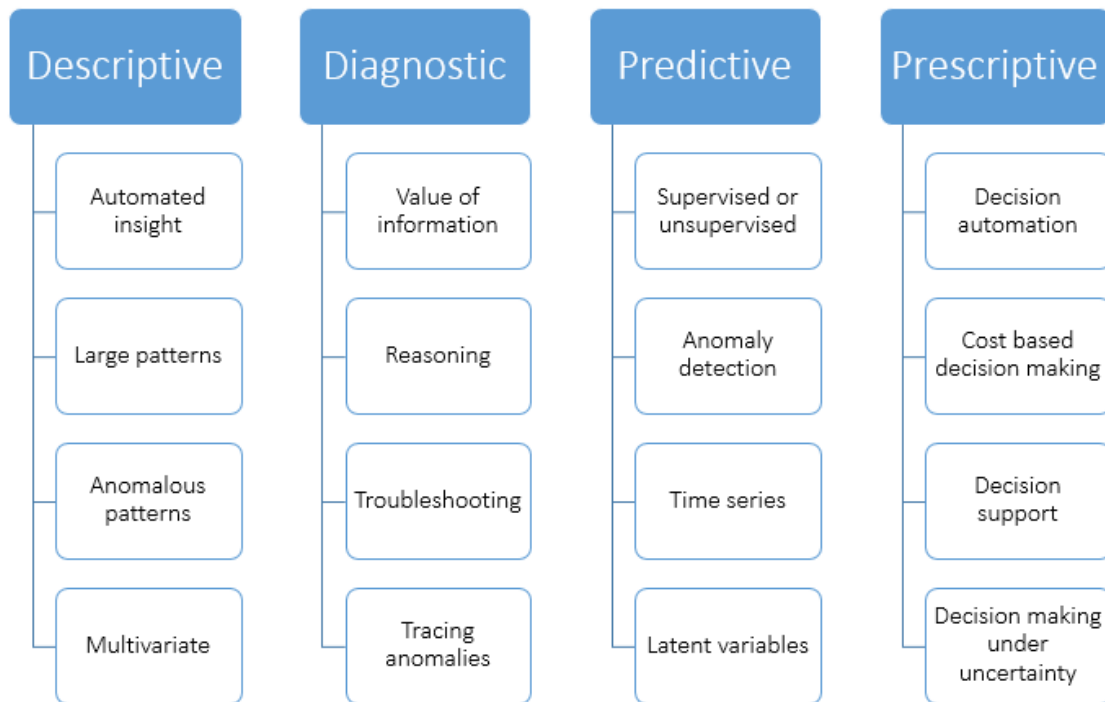
Bayesian Network are probabilistic because they are made from probability distribution and also use the rules of probability for prediction and anomaly detection [8]. The purpose is to think and diagnostics, decision making under vulnerability and time arrangement expectation.

Any nodes in a Bayesian Network is in every case restrictively autonomous of its everything non-descendants given that node's parents. In this way, the joint probability distribution of every irregular variable in the chart put into a series of conditional probability distribution of random variables given by the parents [9]. Consequently, we can make a full probability model by centering just at the conditional probability distribution in each node.

The Bayesian Network is more perplexing than other models, utilizing tens or even several nodes. It is likewise essential to take note of that each node in a diagram ought to be associated with no less than

one edge to another node. Something else, the isolated node is autonomous to every single residual node (additionally to the result variable), and in this manner there is no compelling reason to consider this node [10].

The main weakness is that Bayesian Networks require prior probability distributions. The other weakness is, Bayesian Network need a fully parameter probability model that generally rules out the use of procedures. Where this is not optimal for several model assumptions that strong against a wide range of true situations.



**Figure 2.** Four areas analysing using Bayesian.

#### 2.4. Develop a Bayesian Network

There are two ways to build a Bayesian network. Either manual construction or automatic construction using the databases. Each of this method have their own advantages and disadvantages.

Manual construction of a Bayesian Network accepts earlier expert knowledge of the hidden space. The initial step is to assemble a directed acyclic graph, trailed continuously venture to survey the conditional probability distribution in every node [8].

Not quite the same as the manual construction, automatic learning did not require expert information on the fundamental space. Bayesian network may gain naturally coordinate from the databases utilizing experience-based calculations that previously implicit proper programming. In any case, the inconvenience is that automatic construction puts more necessities on the data. For the most part automatic construction calculations require no missing data in the dataset, which is much of the time an extraordinarily strong doubt eventually.

Bayesian analysis can include estimation or guess probability due to scarcity of data or data not available. It is also required to have enough data to fit the algorithm's requirements for dependable estimates of the conditional probability distribution. For manual construction, the conditional probability distribution is assumed to be a prior known. Automatic learning then involves in both of network structure creation and conditional probability distribution prediction.

### 2.5. Software

There are several types of useful software that deal with graphical models. The most common software is the GeNie, HUGIN, BUGS, and R Software. For this research, we use the Genie software to build the Bayesian network. Graphical models use a conditional probability distribution at each node in the graph. If the conditional probability distribution unknown, it can find from the data using estimation of conditional frequencies of probability distribution.

The calculation and Bayesian Network can be done using the HUGIN software. The software provides graphical user interface allowing for interactive model building and learning [11]. Calculation in the HUGIN software can be done by generate all of the probabilities in percentages. The probability can be obtained by dividing the percentages by 100 percent.

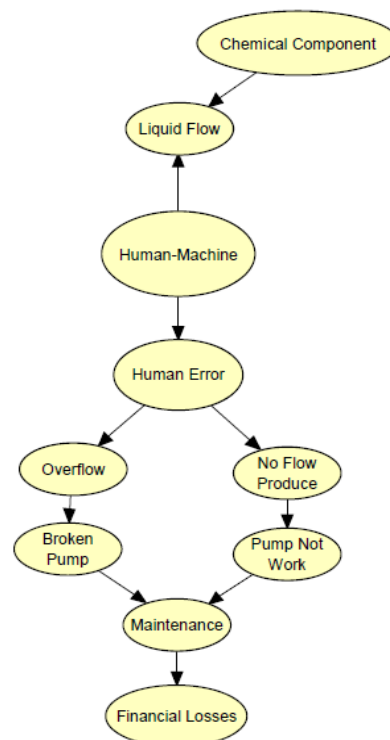
### 2.6. Data Collection

To collect the data related to the accidents during maintenance activity of pump, time limitations have been set to limit the newest accident cases taken. The limit starting from the 1990 until now. The reason is because this time range is the suitable one to get the data and convert it into the probability of failure and human error factors.

The data taken from the report paper that include all the information about the accident. The important part that must include on the data is the overview about the accident, what cause the accident, sequence, background of the accident, the number of victims, and the financial loss.

## 3. Bayesian Network

In order to complete the research, the Bayesian Network has been developed to show the most human factor that cause the accident on the workplace [12], [13]. The relation of the human factors is illustrated in Figs. 3, 4 and 5. The arrow on the Bayesian Network shown the cause-and-effect relation between each factor.



**Figure 3.** Bayesian network for liquid flow

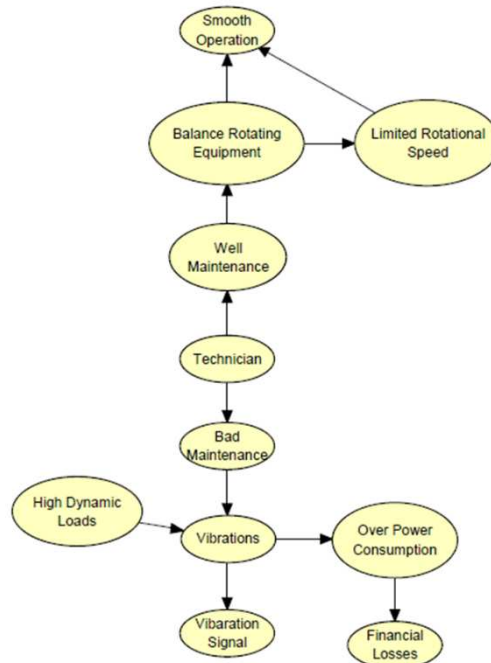


Figure 4. Bayesian network for smooth operation

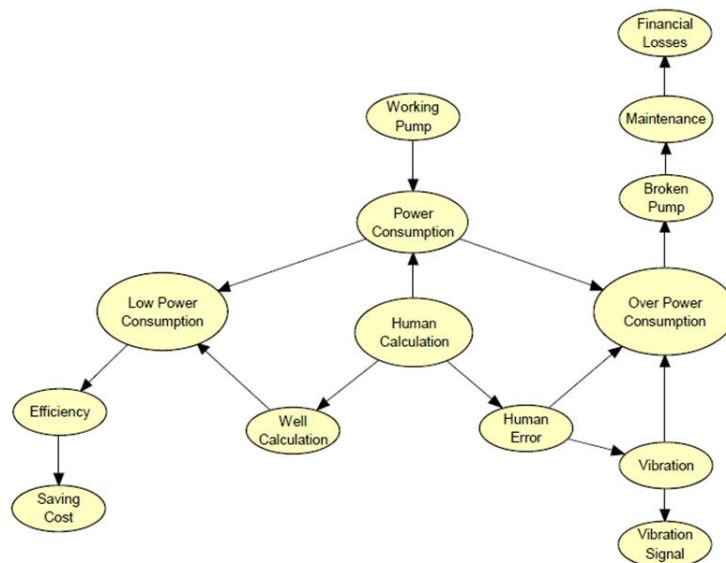


Figure 5. Bayesian network for power consumption

#### 4. Conclusion

Risk assessment is an important procedure in the petrochemical industry. It helps to reduce the number of accidents occur at the workplace. Risk assessment also shown the procedure to handle the accident if the accident already happened. Based on the cause-and-effect relationship Bayesian Network, the probability of failure of equipment has been calculated. Because there is no data yet about the factors of failure, the probability will be initially set to 0.5. The probability will be updated based on data obtained from the investigation report or previous accidents. Based on the updated probability, the financial loss could be estimated for the failure of rotating equipment in the petrochemical industry.

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