A close up of a map

Description automatically generated

Bow Tie Analysis

Fault Tree Analysis

Nuclear Disaster

0.086

Shutdown Failure

0.0856

Human Error

0.08

Increase in Reactor pressure

2.43\*10^-4

Pressure Monitoring System failure

0.081

Loss of power supply

0.081

Cooling System Failure

1.26\*10^-4

Loss of Main Power Supply

0.356

Loss of backup power supply

0.23

Emergency Core cooling system failure

0.00154

Diesel Generator Failure

0.2

Electric Transmission system failure

0.326

Event Tree Analysis

Monitoring of food products & water

Fire reduction Equipment

Probabilities

Outcome

Iodine Pills

Radiation Suits

Evacuation

Success

0.99

Very less damage caused to environment & people

0.0497

People might suffer with thyroid cancer

Failure

0.01

Success

0.95

Death of people around the area

Death of workers

Might cause death

Long term diseases

People suffering from cancer

Radioactive Pollution

High chances of death

Long term diseases to people

Failure

0.01

Success

0.99

Failure

0.01

Success

0.99

Failure

0.01

Success

0.99

Failure

0.05

Success

0.95

Failure

0.05

Failure

0.15

Success

0.85

Failure

0.1

Success

0.9

Failure

0.194

Success

0.806

0.0166

6.931\*10^-3

4.677\*10^-6

4.625\*10^-4

8.864\*10^-5

8.79\*10^-3

2.643\*10^-5

2.578\*10^-3

5.036\*10^-4

Nuclear Disaster

0.086

Bow Tie Analysis

Bow Tie analysis is a risk evaluation method which is used to analyse different factors that can cause failure and also analysing safety methods available after the failure has occurred. Bow tie consists of two parts, Fault tree analysis and Event tree analysis. Fault tree analysis is identifying basic events that can lead to a failure and Event tree analysis is identifying the event sequences from initiating events to accident scenarios.

In this report a Bow tie Analysis of Fukushima Nuclear Disaster is done because in Bow tie analysis all the factors and subfactors that lead to the failures and their respective probabilities are discussed. Bow tie also helps in analysing the steps that can help in mitigating the effects once the failure has occurred. With the help of bow tie analysis, we can decide to work on reducing the probability of failure by improving the reliability of factors causing failure. As Nuclear disaster is very dangerous to human life and environment bow tie analysis is very important in this case.

Fault Tree Analysis

There were many ways that could lead to failure in Fukushima Nuclear power plant. The three main factors were

1. Cooling System Failure
2. Increase in Reactor pressure
3. Shutdown Failure

Cooling System Failure

Cooling system is used to remove the excess heat from the reactor to prevent the meltdown. As cooling is very important there are two systems present for reactor cooling. One system works on electricity from main power supply or backup power supply. Other system is the Emergency Core cooling system which works on steam produced in the reactor and can work for maximum 24 hours. Cooling system failure occurs when all of these systems fail.

Loss of main power supply occurs during natural disasters or due to power station faults or transmission line damage. Probability of Natural disaster occurring in Japan is 0.03 (NHK WORLD-JAPAN, n.d.). Probability of power station faults is 0.076 (Kolawole, Agboola, Ikubanni, Raji, & Osueke, 2019) and probability of Transmission lines failure is 0.25 (Yang, Xiong, Wang, & Weng, 2014). Hence the probability of loss of Main power supply is 0.076+0.25+0.03=0.356.

Loss of backup power supply occurs when the backup diesel generators fail due to insufficient fuel or due to low coolant. Backup power loss also occurs due to natural disasters. Probability of Natural disaster occurring in Japan is 0.03 (NHK WORLD-JAPAN, n.d.). Probability of Diesel generators failure due to insufficient fuel is 0.05 and due to low coolant is 0.15 (Mrowca, 2011). Hence the probability of loss of backup power supply is 0.05+0.15+0.03=0.23.

Emergency core cooling system occurs when either the pump or control system fails. The probability of pump failure is 0.001 (INTERNATIONAL ATOMIC ENERGY AGENCY, 1997) and of control system failure is 0.548\*10^-3 (Cottrell, Jordan, & Blakely). Hence the probability of emergency core cooling system failure is 0.001+0.548\*10^-3=0.00154. Hence the probability of cooling system failure is 0.00154\*0.23\*0.356=1.26\*10^-4.

Increase in Reactor pressure

Pressure in nuclear reactor increases when the pressure monitoring system fails, and safety pressure relief valve also fails. The probability of safety pressure relief valve is 0.003 (INTERNATIONAL ATOMIC ENERGY AGENCY, 1997). Pressure monitoring system fails when there is loss of main power supply and loss of backup power supply or when the pressurizer vessel fails. The probability of pressurizer vessel failure is 10^-6 (INTERNATIONAL ATOMIC ENERGY AGENCY, 1977). The probability of loss of main power and backup power supply is 0.356 and 0.23 respectively. Hence the probability of Nuclear disaster due to increase in reactor pressure is ((0.356\*0.23)+10^-6)\*0.003=2.43\*10^-4.

Shutdown Failure

Shutdown failure occurs when the Seismic instrumentation system fails or due to human error. The probability of Seismic instrumentation system failure is 0.0056 (JUNG, 2013). The main factors that can cause human error are insufficient maintenance and improper operation. The probability of insufficient maintenance is 0.051 and improper operation is 0.029 (Swaton, Neboyan, & Lederman, 1967). Hence the probability of shutdown failure is 0.0056+0.051+0.029=0.0856.

Hence the probability of Nuclear disaster is 0.0856+2.43\*10^-4+1.26\*10^-4=0.086.

Event tree analysis

There are many steps taken when the nuclear disaster occurs for the safety of people and workers.

1. Evacuation

Once the Nuclear disaster occurs the people living within 10 miles of the are evacuated for their safety. The probability of successful evacuation is 0.806 (Heath, Kass, Beck, & Larry, 2001).

1. Radiation Suits

Radiation Suits such as Hazmat suits are used during a nuclear emergency in order to save workers from the effects of radiations. As the nuclear radiations are so powerful, they can pass through the Hazmat suits provided to workers and hence they are not completely safe. Hence the probability of success of radiation suits is taken as 0.9.

1. Fire reducing equipment

Fire reducing equipment is used during nuclear emergency to reduce the fire. Since the fire due to core meltdown or due to hydrogen gas explosion is very difficult to control, the success rate is taken as 0.85.

1. Monitoring of food products and water

After the nuclear disaster, it is very important to monitor the food products and water from the area around the nuclear power plant as there are chances of nuclear particles getting dissolved in water and food products and consumption of these can lead to dangerous diseases. The probability of successful monitoring of food and water is 0.95 (Merz, Shozugawa, & Steinhauser, 2015)

1. Iodine Pills

Nuclear disaster results in release of radioactive materials including radioactive iodine. This radioactive iodine gets accumulated in thyroid which leads to thyroid cancer. Hence the iodine tablets are given to the people for their safety. Since this iodine tablet is highly reliable its probability of success is taken as 0.99.

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