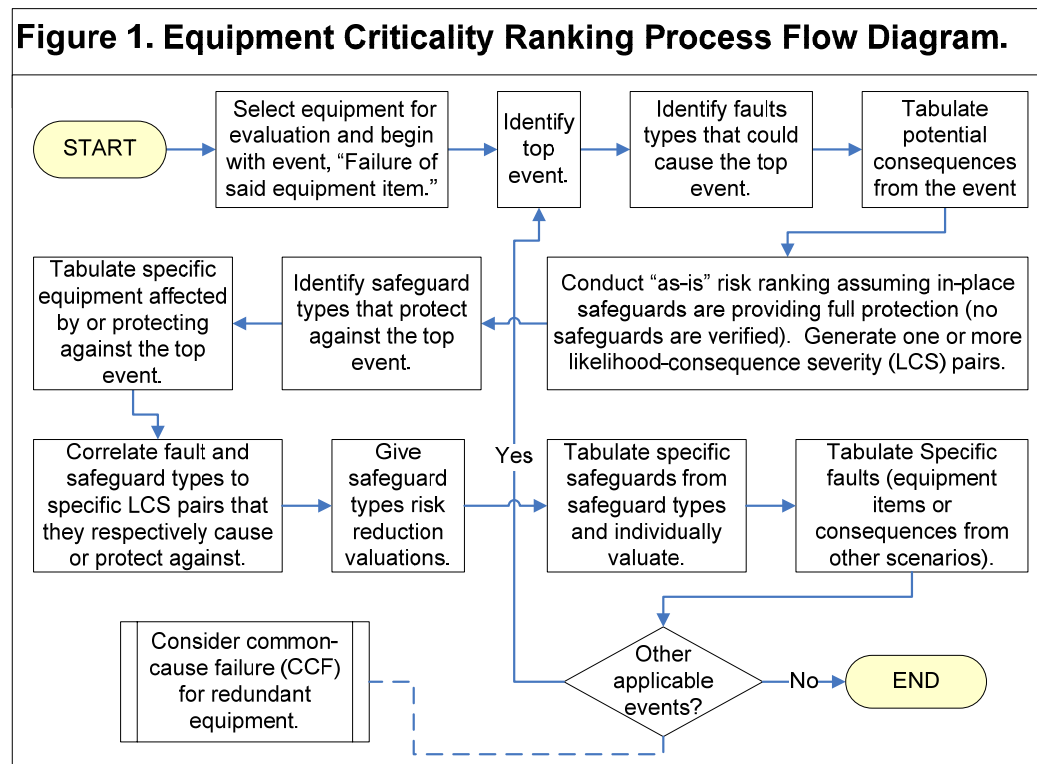


## Summary

The purpose of an equipment criticality ranking (ECR) study is to identify and address potential risk associated with the operation of processing facilities. Failure scenarios are identified, risk-ranked, and risk quantified with consideration given to safeguards that protect against the scenarios. Equipment criticality rankings are a sum of risk from applicable scenarios. Safeguards are identified and prioritized based on the amount of risk reduction they provide.

ECR study data facilitate *safeguard analysis*, a technique used to evaluate benefit-to-cost (BTC) ratios for risk reduction programs and to monitor *safeguard effectiveness*. Safeguards should be maintained or implemented only where safeguard costs give commensurate returns in the way of reduced facility exposure. An enterprise should reduce costs by using BTC analysis to identify and eliminate support programs with low BTC ratios.

Safeguard effectiveness is a measure of actual versus perceived risk reduction for safeguards credited with reducing risks. Automated exception reporting can be used to monitor safeguard effectiveness and to notify personnel when intervention is required to intercept a potential loss before it happens.



## Methodology

Equipment Criticality Ranking (ECR) is used to assess risk and exposure levels associated with processing facilities. It is a systematic process for identifying potential equipment failure scenarios, risk-ranking and quantifying exposure for each scenario, and then aggregating exposure at any point within a facility. Scenarios are

developed with progressive levels of detail on an equipment-by-equipment basis and include fault-event-consequence sequences, consequence risk ranking, other equipment involved or affected, and other applicable details. Figure 3 gives the ECR process flow.

Exposure (risk) is quantified hierarchically by functional area location (FAL) based on scenarios applicable to lower FAL levels in the functional location structure. Exposure can be quantified at any level in the structure. Exposure at a given level  $N+1$  usually is less than the sum of exposure for its child functional locations at level  $N+1$  as scenarios are almost always applicable to more than one functional location. Failure scenarios are classed into the following risk zones:

1. Red: unacceptable risk, action required
2. Gray: borderline acceptable risk, action should be evaluated
3. White: acceptable risk, no action required

A *Criticality-Based Mechanical Integrity Database* is used to capture and manage ECR study data.

## Safeguards

The fundamental premise of a *Criticality-Based Mechanical Integrity (CBMI)* program is that most activities associated with operation, and maintenance of processing facilities are done with the intent to ensure optimum production and safety. Therefore, those activities can be assumed to safeguard against unwanted consequences, specifically operating hazards and production loss. Safeguards include but are not limited to safe job procedures, training, preventive and predictive maintenance, inspection programs, installed protective equipment, and equipment spare parts.

Each safeguard provides an incremental amount of risk reduction, either by reducing the likelihood of an unwanted scenario or by reducing the potential consequences of that scenario. For example, reducing inventory of a hazardous chemical in a tank would reduce the consequence of a spill resulting from that tank, while routine corrosion monitoring on the tank would reduce the likelihood of the leak from occurring. Either way, the exposure level is incrementally reduced and remains lower provided that the safeguard continues to provide the intended/assumed risk reduction amount.

Safeguards should be discretely identified and given risk reduction credit for each scenario in which they are involved. A safeguard priority rating can then be given by the following equation:

$$S_T = \sum_{i=1}^n \{ (L_i C_i - l_i C_i) + (L_i C_i - L_i c_i) \}$$

Where:

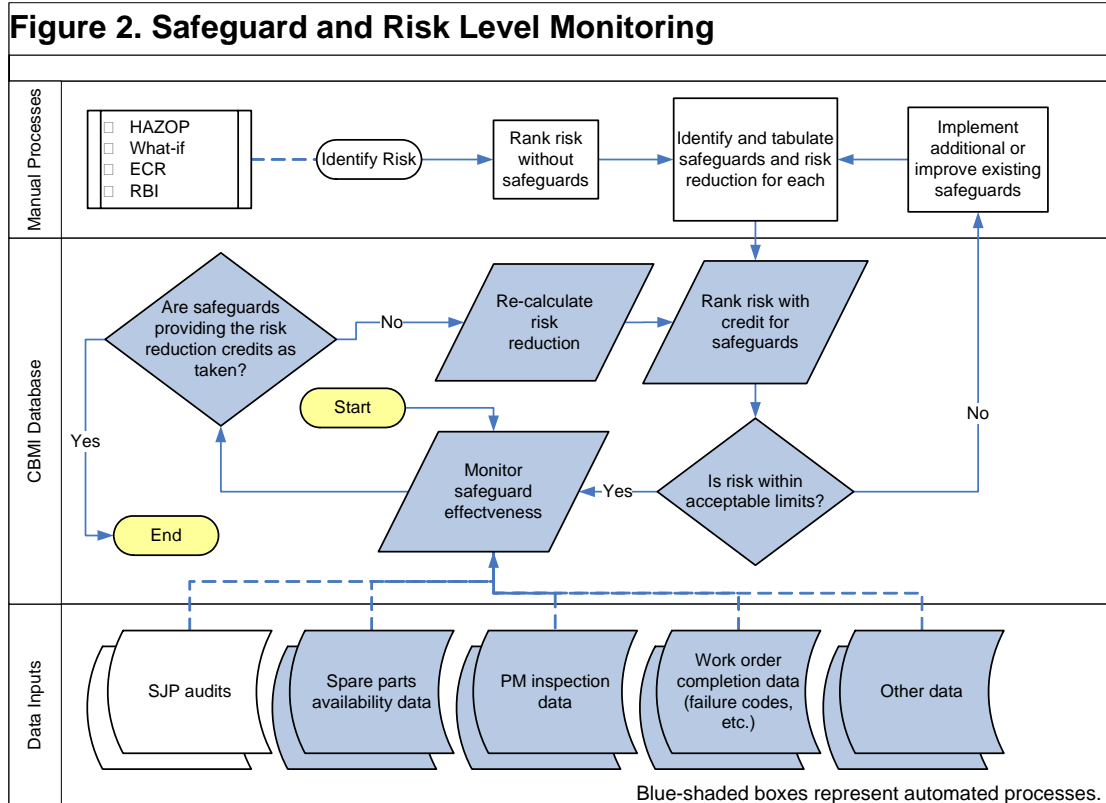
- $S_T$  = Total safeguard risk reduction for  $n$  scenarios  
 = Safeguard priority rating  
 $L_i$  = Likelihood of consequence  $i$  before application of

- $C_i$  = Consequence of scenario  $i$  before application of safeguard  $i$
- $l_i$  = Likelihood of consequence  $i$  after application of safeguard  $i$
- $c_i$  = Consequence of scenario  $i$  after application of safeguard  $i$

## Safeguards Analysis

Safeguard analysis is used to evaluate benefit-to-cost (BTC) ratios for risk reduction programs and to monitor safeguard effectiveness. Safeguards should only be maintained for those programs where the costs give commensurate returns in the way of reduced facility exposure. Table 1 gives examples of safeguard BTC analysis.

Automated exception reporting can be used to monitor safeguard effectiveness and to notify personnel when intervention is required to intercept a potential loss before it happens. Table 2 gives an example of such reporting for materials safeguards. Criteria are established to identify when a safeguard is compromised; when a criterion is exceeded, the compromised safeguard will appear as a report line item. The criterion for the example in Table 2 is a stock-out situation.



**Table 1. Examples of Benefit-to-Cost (BTC) Evaluations for Safeguards.**

Item notes (risk zones for items not shown):

1. The BTC Ratio is low and pre-safeguard risk is in the white zone. No action recommended.
2. The BTC Ratio is greater than 0.5 and pre-safeguard risk is in the gray zone. The safeguard (spare bundle) lowers risk into the white zone. This action is recommended.
3. This item evaluates risk associated with removal of a safeguard. Risk would increase from white zone to red zone if this change was made. No action/change to PM recommended.

Item	Exposure	Scenario ID	Event Description	Action	Cost	New Exposure	Risk Delta	BTC Ratio
1	\$ 1,100	1817	Failure of TP2 crude feed/cold residue exchanger	Add tube bundle to stock	\$ 13,000	\$ 1,010	\$ 90	0.007
2	\$11,000	1821	Failure of one desalted crude/hot residue exchanger	Add tube bundle to stock	\$ 13,000	\$ 2,000	\$ 9,000	0.692
3	\$ 2,000	2434	Common cause failure of Caterpillar field gensets	Increase service interval to 3000 hours versus current 1500-hr interval	\$ (876,000)	\$ 2,000,000	\$(1,998,000)	2.281

**Table 2. Example of an Automated Safeguard Effectiveness Report for Materials Safeguards.**

Risk Delta (US\$)	Scenario	Consequence Description	Material	Material Description	On Hand
\$ 9,000	Failure of one TP1 crude feed/hot residue exchanger	Topping Plant 1 shutdown	108182	Exchanger, bundle & exchanger head crude feed/hot residue Product & Diesel PLT# e-21034A/B dwg# 925-209-a w/ bundle & exchanger head gaskets	0
\$ 90,000	Failure of topping plant residue pump(s)	Topping Plant 1 shutdown	128186	Pump, centrifugal 2x3x13 model VLK I/ motor duplicate of S/N CH92290AX ATM residual 158 GPM API class S-6 steel casing material 12% chrome SS impeller 12% chrome SS wear ring 12% chrome SS shaft 300 ANSI RF flanges carbon 316 SS backed throat bushing di	0
\$ 90,000	Failure of topping plant residue pump(s)	Topping Plant 1 shutdown	129848	Seal, mechanical John Crane 609 (715) tandem drawing #HSP-1005864-1 w/ pumping rings / glands / heads with mating rings f/ 3 x 4 x 13C VLK pump	0