Chapter 9: Operating Equipment Risk Assessment

Risk is an amount of loss or gain. A risky situation implies that a range of outcomes exist. The risk of investing money in the stock market brings with it the possibility of great reward as well as the possibility of serious loss. The challenge is to develop methods to increase the likelihood of a good outcome while removing and controlling bad risks. Because risk has such a profound impact on everything to do with business and commerce, it is critical to understand it. Once you have a good perspective on risk, you will be better able to identify the risk management strategies that will provide the greatest financial, production, and safety benefits to your organization.

Risk is virtually impossible to reckon exactly because it is probabilistic—a situation might happen like this, or it might happen like that, or it might not happen at all. Risk management specialists try to model and quantify risk to give it a firm value, but the results are notoriously misleading because real-life situations are unlikely to go the way they were imagined while sitting in the office, unless they follow a well-defined and well-rehearsed script. Identifying the full profile of risk—the range of its total makeup and the depth and the extent of each component risk—is the first step in understanding the scale of risks in a situation. Once you know the size and nature of the risks you face, you can pick effective mitigation strategies.

Estimating Risk

The calculation of risk is straightforward and can be done mathematically in a spreadsheet or determined with the help of a risk matrix. As noted in Chapter 4 and repeated in Formula 9.1, risk is equal to the likelihood of an event occurring multiplied by its cost consequence should it occur.

Formula 9.1

Risk ($/yr) = Consequence ($/event) x Likelihood of Occurrence (events/yr)

The likelihood of occurrence is measured by the number of times an event happens during a period. Usually, a year is used so that risk can be annualized. An event that happens every five years has an annualized likelihood frequency of 0.2 times a year. The consequence of an occurrence is the total financial impact of the event. By calculating the likely frequency of an event per year and valuing the consequence of occurrence, the risk formula calculates the annualized cost of the risk. It is a means to quantify the yearly cost to an organization of every risk event that it may suffer, good or bad. It provides a figure to weigh one risk against another and thus allows you to address your worries in a justifiable order of priority.

The likelihood of occurrence can be further divided, so that the full risk formula is as follows:

Formula 9.2

Risk = Consequence ($) x [No. of Opportunities (/yr) x Chance of Occurrence at Opportunity]

The number of opportunities is how many times a specific situation that could lead to a failure arises per year. The chance of occurrence (or probability) is the odds that a situation results in a failure. Chance equals one (1) if there is a sure failure every time the situation arises and zero (0) if there can never be a failure. Probability takes a value between 1 and 0 because the chance of something going wrong is possible to a larger or a smaller degree. Risk elimination is when you drive the risk to zero by having either no consequences from the event, no opportunities for the event to occur, or no possible outcome even when opportunity arises. Risk mitigation applies risk controls to reduce the consequence, opportunity, or chance but does not completely eradicate the effects of an event.

There are great benefits available to businesses that reduce their risks of failure. When the chance of a failure falls, money is saved because fewer money-losing events happen during the period. As a simple example, take a failure event that happens twice a year and costs $10,000 each time it occurs. Using the standard risk formula, the risk is calculated as follows:

Cost of Risk = $10,000 per event x 2 events per year = $20,000 per year

By introducing risk-reduction strategies that lessen the chance of the event to once every two years, the diminished risk becomes

Cost of Risk = $10,000 per event x 0.5 events per year = $5,000 per year

Mitigation delivers savings of $15,000 per year, year after year. If the cost of reducing the risk to once every two years is less than $15,000 per year, then the company makes money by preventing the risk. The challenge is to select strategies that cost the least but realize the greatest risk reduction.

A Practical Way to Assess Allowable Frequency Using the Risk Formula

When risk is underpriced, wrong decisions can result, and insufficient protective measures are taken against the real likelihood of failure. Making decisions involving risk without understanding both the likelihood of an incident occurring and the full cost of its consequences can have ominous implications for a business. In situations involving risk, it is necessary to identify the various scenarios that may happen and estimate their individual cost and probability of occurring.

The risk equation requires users to know the chance and the consequence before risk can be determined. The cost consequence is the worst financial impact of the incident; it is found by assuming the worst-case scenario and calculating costs using TDAF costing. What is not easy to determine is the “chance” factor for an incident. Because an incident requires several permitting causes to occur in sequence or together, and each has its own degree of chance, the probability of all factors happening is never more than a hopeful estimate—a guess. Few businesses want to use guesswork as their strategy for profitability.

In a risk analysis, you look at the recorded history of an incident to determine a typical frequency. Alternatively, you can use industry databases if they are available and reflective of the situation under consideration. When there are insufficient or no historical data for an incident, then laboratory and controlled trials and tests can estimate the conditions under which a failure incident could occur. From those tests, you conduct a scientific analysis and engineering review to estimate the probability of the event occurring. This is better than guesswork, but no one knows how much better because of the many assumptions needed to arrive at the estimated frequency.

You can be sure that the consequence value is reasonably accurate if TDAF costing is used to calculate the total cost. But you can never be certain that the frequency figure is correct, or even close to correct, unless there is a long, unchanged history of the incident occurring. If historical records are complete and accurate, you can use them as evidence of event frequency. For those loss incidents that hardly ever happen or arise infrequently, the estimated risk could be terribly wrong. The situation is further complicated when the chance of an incident occurring is altered by new improvement projects starting unknown interactions, when new decisions alter future choices, or when new changes bring together previously unconnected causes. It requires only one factor to influence an incident, and the future event frequency can be completely unlike its past history. This uncertainty raises two questions: If the frequency figure in a risk equation is so uncertain, why try to estimate it? Why base your decisions on something so unpredictable? When the frequency is chancy, then there is another way to use the risk equation and get value from it.

By simple mathematical manipulation of the standard risk formula,

Formula 9.3

Likelihood = Risk / Consequence

With the equation written in this form, we have a better command of risk. Your annualized risk boundary is used to set a limiting likelihood that you will not pass. No longer do we need to wait in stressful expectation of a failure, wondering when it will happen. Instead, we decide how much risk to carry in our business and then implement the risk-control methods needed to produce that outcome. You become proactive against failure, driving down risk to the required event frequency that gives you an acceptable level of risk. If we have a risk for which the TDAF cost consequence is $100,000 but the frequency is uncertain, we can guess the frequency and hope that we are right. Or we can decide that we do not want to carry a risk greater than $10,000 per year and use the risk equation to identify the frequency that we are prepared to accept.

Likelihood = Risk / Consequence

= $10,000 per year / $100,000 per event = 0.1 events per year (Once in 10 years)

The frequency is no longer guesswork. Knowing that we need 10 years between events lets us develop and implement risk mitigations that reduce the chance of the event to the required frequency. Resources and money can be devoted to accomplishing this with greater certainty of achievement. This is a more useful way to use the risk formula than hoping that an estimate of frequency is close to being right and wondering whether the current business systems and practices will provide that level of protection. A second benefit of using the risk equation in this way is knowing how much you are paying for risk control. To ensure that an event that costs $100,000 occurs no more often than once in 10 years, you can justify paying up to $10,000 per year, or $20,000 every two years, or $50,000 every five years to prevent it. If it costs less than an equivalent $10,000 annually to prevent the once-in-a-decade $100,000 risk, you'll make more operating profit. If the least costly mitigation is more than $10,000 per year, then the risk is greater than you estimated because your minimum loss is always the value of the least cost consequence. The justification of your risk control choices depends on the nature and size of risk you face. Gaining full appreciation of risk complexity is vital if you are to make the best decisions.

Equipment Operating Criticality

You need to know how bad an equipment failure can be for your company. Events that harm people or the environment or destroy the business can never be allowed. Your business-wide risk from equipment breakdowns and quality failures is far greater than just the risk to production. *Operating criticality* indicates an asset's severity for your operating future. It measures the business-wide risk that an equipment failure causes the company. It is used to rate equipment in priority order of importance to the continued operation of a facility. Equipment that stops production or causes major production costs when it is failed is considered the most critical. Once criticality is known, resources, engineering effort, operating practices, maintenance, and training are matched to the priority and importance of the asset's continued operation.

The Plant Wellness Way methodology diverges from the standard criticality method by using two meanings in its rating of operating criticality. It first presumes that the worst outcomes will happen, including the death of employees, destruction of the environment, major plant and equipment loss, and plausible "acts of God" such as lightening and serious bad weather damage. The assumption of sure catastrophe makes an asset's initial operating criticality rating equal to the TDAF cost, because the likelihood of failure is taken as certain and so probability becomes 1 in the risk formula. By identifying the worst consequence from a failure, you are aware of the severity of a calamity. It is recorded as "Operating Criticality 1" to differentiate it from the standard criticality that uses historical failure frequency in the risk formula. The standard operating criticality that includes likelihood effects is identified as "Operating Criticality 2" in the criticality analysis spreadsheet. Knowing the full range of an asset's risk profile encourages better life-cycle engineering, operating, and maintenance decisions to be made so that you manage all risks with a higher certainty of success.

When you adopt the Plant Wellness Way in your operation, you are required to reduce risk with mitigations that lower the chance of equipment failure to frequencies not expected to happen during three times an asset's working life. The primary strategy is risk elimination, whereby you remove all opportunities for an event to arise by using effective solutions throughout the life cycle. The next strategy is to make the asset so robust and reliable against the event that it does not fail even if the opportunity occurs. The third strategy is to use procedural quality controls in the manufacture, installation, use, and care of the asset. Selecting actions that only limit the consequential loss are not preferred mitigation options for Plant Wellness Way practitioners. To control risk by reducing consequence and not by eliminating or preventing the likelihood of the failure cause means that a business is hoping that luck will always be in its favour. That is an impossibility. Limiting risk by minimizing the financial consequences of a failure is not risk management based on good judgement and sure risk control. In the Plant Wellness Way, you do not dismiss the use of consequence reductions, but they are choices considered to be a last resort, used in combination with chance mitigations when it is necessary to drive risk to as low as is possible. For example, if there was a risk someone could suffer injury, choosing to make an ambulance available is consequence reduction, but providing the ambulance will not keep your people safe. It is not a risk prevention; it is a risk control. The right risk management strategy to use is injury elimination—have no chance of injury in your company. An ambulance can never protect your employees from harm, but it may keep them from dying.

A catastrophic failure event is not acceptable under any circumstances. Examples of intolerable outcomes are immediate or long-term risk to human life, total or substantial operating plant destruction, loss of a major customer, or catastrophic environmental incident. It is unnecessary to ponder the frequency of horrific events because they are so bad that everything must be done to stop them. Even if a disastrous event were to happen once in 100 years, it would cause such severe effects that it must never happen. It is impossible to predict when a one-in-10-year, or a one-in-100-year, or a one-in-1,000-year failure will occur. It could be tomorrow. Such failures are controlled using appropriate engineering, fabrication, and construction quality controls, coupled with effective operational and maintenance methods, systems, and practices that provide lasting asset integrity—not by hoping they will not happen.

Beware when standard equipment criticality multiplies consequential cost by a low likelihood of an event occurring. The devastating impact on the business is hidden by the resulting low risk value. If you disregard major events because their frequency is low, you guarantee that catastrophes will happen in your operation from time to time. Because a small risk value makes you discount low-risk events, you can have many perils all around you. In an operation carrying numerous unaddressed low-chance, high-cost opportunities, there will be a steady stream of disasters. The next one is waiting just around the corner. By seeing risk as an annualized cost that looks very low, you are tricked into making wrong decisions—or making no decisions—believing that the risk is sufficiently controlled. You're easily led into not considering that catastrophic incidents eventually transpire if they are not prevented. If an operation accepts many disastrous risks with low frequency of occurrence, the odds worsen with time that one or more will happen. As the years go by and a failure has not yet occurred, the chance of the event rises as protective systems degrade, uncontrolled modifications are made, management's focus changes, experienced people are replaced by those less experienced, people become complacent, and numerous other reasons that cause disastrous events and catastrophes. Unless precautions are vigilantly maintained, the worst failure event becomes increasingly possible.

Determining Asset Operating Criticality

Identifying an operating equipment's risk profile is determining its operating criticality—it is an operating risk rating of the asset's effect on the whole business. Operating Criticality 1 is the total value lost should the item being assessed fail. The cause of failure is not considered, only the total waste, losses, and costs resulting from failure are tallied. It is estimated using Formula 9.4.

Formula 9.4

Operating Criticality 1 ($/yr) = TDAF Cost Consequence ($) x 1 (/yr)

Formula 9.5 is the risk equation used to gauge Operating Criticality 2 from historic failure events.

Formula 9.5

Operating Criticality 2 = Business Risk ($/yr) = TDAF Cost ($) x Failure Frequency (event/yr)

Operating equipment carries a risk of failure from every critical working part in it. It also carries risk from external sources such as forklift damage, consequential damage from the failure of nearby equipment, earthquakes, lightning strikes, and so on. Operating criticality is the total business risk incurred by having the equipment, and it is determined by adding together all the annualized risks that are not mutually exclusive.

Separately identifying Operating Criticality 1 as the TDAF cost of sure failure prevents you from ignoring risks that would be considered minor by traditional rating methods and forces consideration of the necessary precautions to prevent them. Knowing your Operating Criticality 1 value is vital for making fully aware business risk choices. Once Operating Criticality 1 is established, you again review the failure scenarios for an equipment item to calculate Operating Criticality 2 values. This is a standard risk analysis that reviews critical assemblies, subassemblies, and parts using the likely frequency of their failure.

Formula 9.6 indicates how the risks from individual working parts in an asset are summed to determine Operating Criticality 2.

Formula 9.6

Operating Criticality 2 =

[TDAF Cost Consequence$_{\text{Part 1}}$ ($) x Failure Frequency $_{\text{Part 1}}$ (/yr)] +

[TDAF Cost Consequence $_{\text{Part 2}}$ ($) x Failure Frequency $_{\text{Part 2}}$ (/yr)] +

[TDAF Cost Consequence $_{\text{Part 3}}$ ($) x Failure Frequency $_{\text{Part 3}}$ (/yr)] +

[TDAF Cost Consequence $_{\text{Part 4}}$ ($) x Failure Frequency $_{\text{Part 5}}$ (/yr)] + . . .

[TDAF Cost Consequence$_{\text{Part n}}$ ($) x Failure Frequency$_{\text{Part n}}$ (/yr)]

An asset can suffer hundreds of concurrent risks, making the calculation of operating criticality daunting. To reduce the calculation, it is common to include only the bigger risks. Events that might happen once in 100 years or more are assumed to be so rare, and their annualized cost so small, that they are negligible in comparison to large risks. It is a mathematically convenient practice to disregard them to allow the quick determination of criticality. But ignoring large-consequence events with little possibility of occurring does not stop them. When you have hundreds of them sitting in your business, you'll be regularly involved in major problems.

Another convenient practice is to consider only failure events that can or may happen in an operation. Such events are failures that have occurred previously in a business or have happened in comparable organizations. Often the problems that can arise in an organization have not yet occurred, and there is no history of failure from which to determine a likelihood of failure specific to the situation. In this case, you research other companies in your industry that have suffered the event, and, after considering your operation's reliability practices, you determine an estimated likelihood to use in the risk calculation.

There is one other class of risk scenarios to be aware of that people usually skip over—those that have never happened in recorded history. What has not yet happened still can happen. Not everything that can go wrong has gone wrong, and only using historical incidents as justified inclusions in assessing operating criticality neglects other plausible events that have not been experienced but could occur. Risk scenarios that have not happened are known as "black swan," a reference to the discovery of black swans in Western Australia when only white swans had ever been seen. Having a huge Operating Criticality 1 value warns you that every major failure will be a catastrophe for you. When you could lose massive amounts of money from a failure, it is well worth consider all the things you don't know about a situation and intentionally imagining black swan events so that you can protect against them.

An approach often used by industry is to substitute "cost consequence" with a scale based on the impact of an event's production disruption, for example, no impact = 0, two-hour production loss = 1, half-day production loss = 2, full-day production loss = 3, and so on. The "failure frequency" is derived from the company's maintenance history or industry norms for a similar operational situation. This is not done in the Plant Wellness Way method for operating criticality. A key premise of the Plant Wellness Way is that you are building a world-class business. To make the best business decisions, it is necessary to know the real financial worth of the business-wide losses, waste, and costs of a failure, not just its impact on production uptime. Unless the true and total business-wide costs are included in determining operating criticality, the real risk of an equipment failure to the business is not appreciated. A failure that lost $1,000,000 in profit means more to people than the same failure described as a two-day outage. Using TDAF costing gives an accurate value of consequential loss and leads to a truer, more relevant operating risk assessment.

One of the great business benefits from using operating criticality is showing everyone how much company profit is destroyed by a failure. Once you have a complete total of all costs, waste, and losses for equipment downtime, you ought to publish the hourly operating income lost for each critical equipment that breaks down. The value lost with every hour of breakdown focuses people on doing what is important for both the business's well-being and protecting their own job and income.

Talking to a company's senior management about how to make money will catch their attention. When you have the full cost of a failure for an asset and its expected frequency of loss, you can do economic modelling of risk reduction choices and pick the most profit-making option.

Knowing the true worth of business losses from equipment breakdown helps you make a powerful business case to management to remove the failure causes because you know the real benefits and new profits that the proposed risk reductions will bring to the operation.

Conducting a Risk Analysis

When doing an operating criticality analysis, a competent team of people are brought together to identify risks for a facility. Normally, a database of TDAF costs for the operating assets is developed. That database is used to populate calculation spreadsheets and makes the analysis quicker and easier. Typically, the review group consists of the operators, maintainers, and engineers of the plant who contribute their knowledge and experience. The group reviews process maps, the production process, the engineering design drawings of the item, and manufacturer's information of its equipment. For each operating equipment, they analyse the business-wide consequences of failure and develop a table showing each equipment's Operating Criticality 1 and 2 ratings. It is convention that the final arbiter of a choice is the operations or production group, as it must live with the consequences and costs of a failure.

The people involved with the equipment risk assessment need to do the following:

1. Understand the equipment operation and design—the operator manuals, maintenance manuals, and manufacturer's design drawings contain this information
2. Comprehend the impact severity on production of losing use of the equipment; this information is contained in plant drawings, process flow diagrams, and process and instrumentation diagrams
3. Know the business-wide financial loss from each forced outage to put a true value to the TDAF costs for each downtime event

4. Know the effects on business reputation and the impact on clients of forced outages
5. Review and adopt the risk assessment methodology in reputed risk management standards
6. Calibrate the risk matrix using the information developed from the foregoing steps and the advice of experienced and senior people in the operation

Using the Risk Matrix to Gauge Risk

Gauging operating risk requires an estimate of the chance that a particular piece of equipment will fail. Quantifying chance involves calculating the probability of occurrence. This is a difficult requirement unless you are trained in probability mathematics and methods, and you have kept complete and thorough failure history for every failed component and replacement part installed during the life of an asset. If you have, then you can quantify the likelihood of equipment failure and readily determine the operating risk of the equipment. If you have not trained in probability and statistics, or the historical failure data do not exist, or your data is incomplete and unreliable, you can instead use the likelihood scale of a risk matrix for allocating equipment failure frequency.

In the Plant Wellness Way, the risk matrix is used to see the financial impact of risk before and after its mitigation. The matrix is a visual financial decision-making device. The financial worth of consequences can be calculated, and their value shown on the risk matrix. The likelihood of events is the frequency of failure incidents. The two charted together—consequence and likelihood—cross at an identifiable cell in the matrix. Once a cell is identified, you have a risk level—acceptable, low, medium, high, or extreme—and a risk value from the cell for the event. Plotting current and mitigated risk on the matrix allows you to see risk move from the current point to a future point as you make choices about how to control your risks.