Chapter 12: Chance Reduction Risk Management

You might think that it does not matter how you choose to reduce risk, but you would be wrong.

The standard risk formula can take the following form:

Formula 12.1

Risk = Consequence x Chance

Reduce the chance of an event occurring or lower the consequences of an incident, and risk is reduced. It seems as if either strategy—consequence reduction or chance reduction—will produce the same effect. Halving the consequences is as equally good as halving the chance. The math says it is. However, the two "paths" to reducing risk have totally different impacts on the prosperity of an organization. The application of basic accountancy is sufficient to explain why the best risk management path is to reduce the chance of failure and not its consequence.

Impact of the Choice of Risk Reduction Strategies

Figure 12.1 shows the "death by a thousand cuts" production breakdown model presented in Chapter 4. Each breakdown causes a loss of production time and a business-wide cost surge. Companies using consequence reduction strategies minimize their losses by learning to fix breakdowns quickly. They hold lots of spare parts in store, set up a parts cache by key machines, use "gun" repairers to fix things speedily, and change access to equipment to do fast repairs. Figure 12.2 shows the reduced production time loss when you follow a consequence reduction strategy.

A comparison of Figures 12.1 and 12.2 confirms that reducing downtime increases profit. Losses are minimized when the plant gets back to production quickly. Consequence reduction strategies do reduce risk.

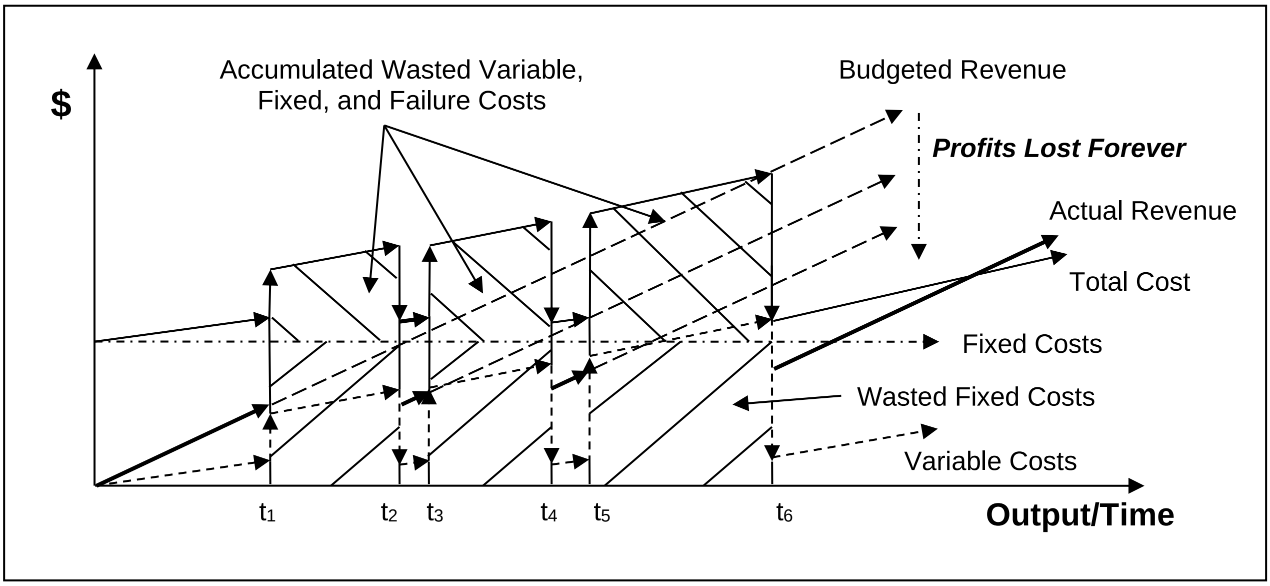

Figure 12.1—Effects on Profitability of Repeated Failure Events (Death by a Thousand Cuts)

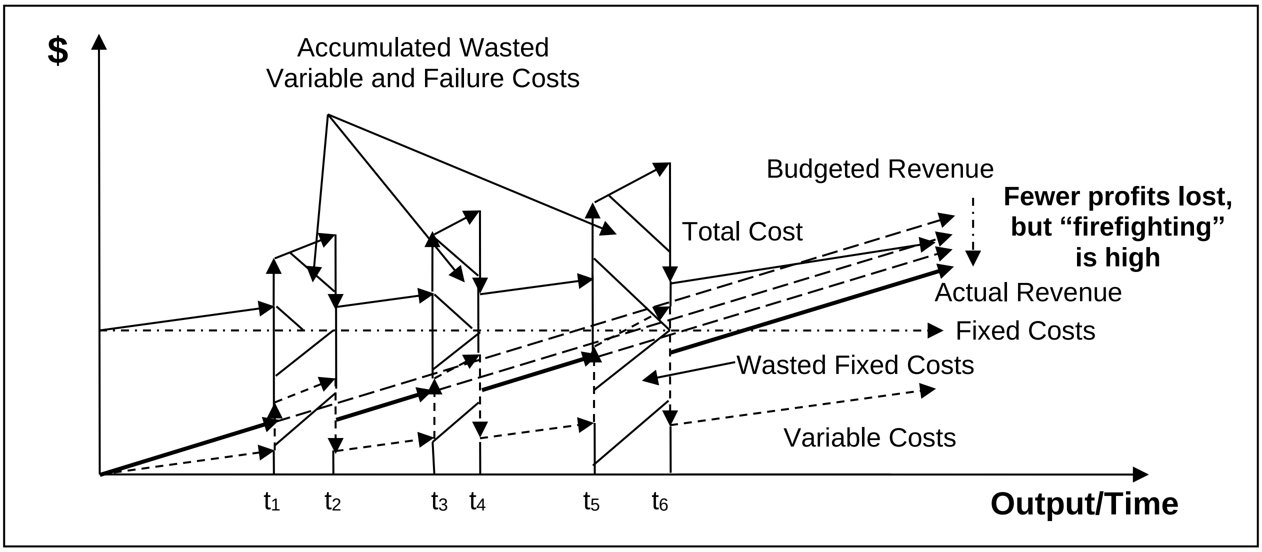

Figure 12.2—Effects on Profit by Reducing Consequence Only

What's interesting about the consequence reduction model is that although costs are lower, there will be much frantic activity and "firefighting" as people go from one failure to the next. In these operations, you wait for failures because they may not happen. But there is a serious misunderstanding in this logic. One risk may not occur, but if you have 10,000 potential risks in your business, some will always arise. Today you might fight fires and put them out, but tomorrow different ones will blaze. It will be the same next week, next year, and for your whole career. If there are 100,000 risks in your operation, you have a never-ending nightmare of a business. In organizations that primarily use consequence failure management, things are always going wrong.

Minimizing risk by reducing its consequence means accepting failure as a normal way of doing business. Sites that use such a strategy instil a reactive culture in their operation. If you walk about in these companies, you see that everyone is busy, but little of their time and effort adds value to the operation—the time spent fixing problems only adds more cost. The breakdowns repeat over and over. Reducing only the consequence of risk still makes work for everyone because reliability is no better. Instead of improving the business so that it can be more profitable, people waste time, money, and effort fixing failures and repeatedly correcting the same problems.

An alternative risk management strategy is to apply chance reduction techniques to proactively eliminate the possibility of failure. With this approach, you identify failure scenarios and prevent their causes. As more and more failure causes are eliminated, fewer production stoppages result. Figure 12.3 indicates the effect of using chance reduction strategy to reduce breakdowns from three in Figure 12.1 to only one incident during the same period. Less profit is lost when there are fewer failures because TDAF costs are not incurred. Chance reduction strategy is far more lucrative than consequence reduction strategy because failures don’t waste your resources and rob you of profit. Improving reliability by stopping opportunities to start failures and by making processes resistant and resilient to failure are profit-making strategies.

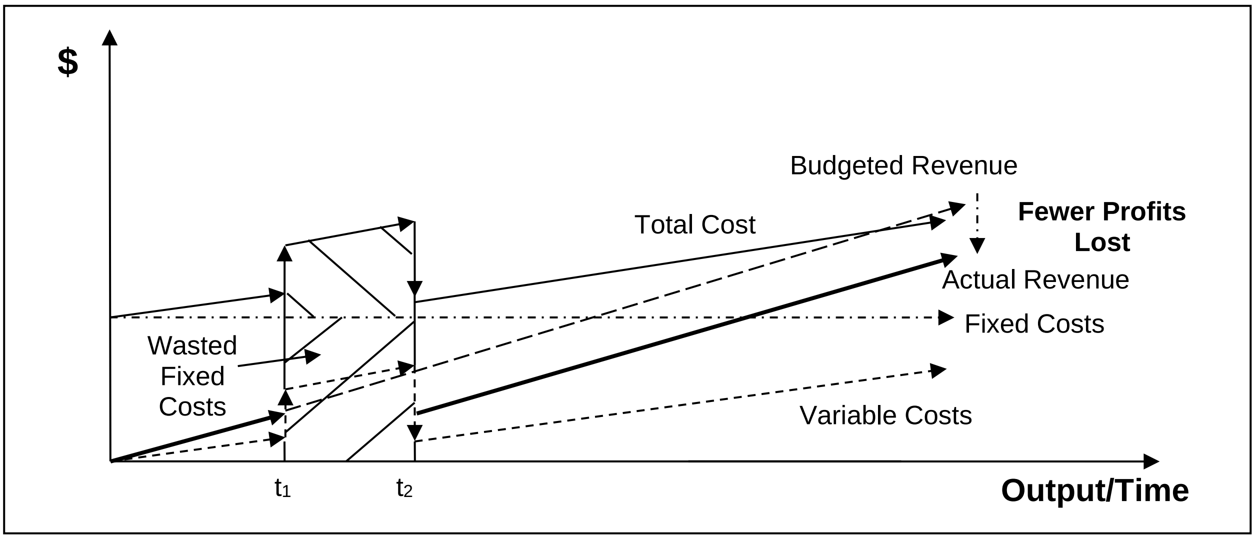

Figure 12.3—Effects on Profit by Reducing Chance Only

Your choice of risk management strategy matters because only chance reductions stop problems, whereas consequence reductions can never do that. They can lower your losses from an incident, but they can't create reliability so there is no incident. Controlling consequences is important. The fire brigade, ambulance, police, insurance companies, personal protective equipment, and condition monitoring of machinery are all worthwhile consequence reduction strategies. They do not reduce the chance of failure, but they can save you fortunes in operating losses and stop a bad event from becoming a major disaster. Even though consequence management costs money to do, it makes a difference to the total cost of a risk, and there is a place for it in workplace safety, asset management, and maintenance management strategy.

A complete business risk management strategy is to use both chance reduction and consequence reduction to maximize profit. It is far better not to have a failure, but if one does happen, you need to quickly minimize its impacts. Your business processes need to be good at doing both strategies well. The benefit of using the combined strategy is evident in Figure 12.4, in which both lost time and failure frequency are reduced. When risks exist, pursuing a combined risk management strategy delivers the least profit loss. When no chance of risks exists, you don't have to do anything because nothing goes wrong. That makes chance reduction strategies the best business choices by far, because they eliminate consequences and retain all operating profit.

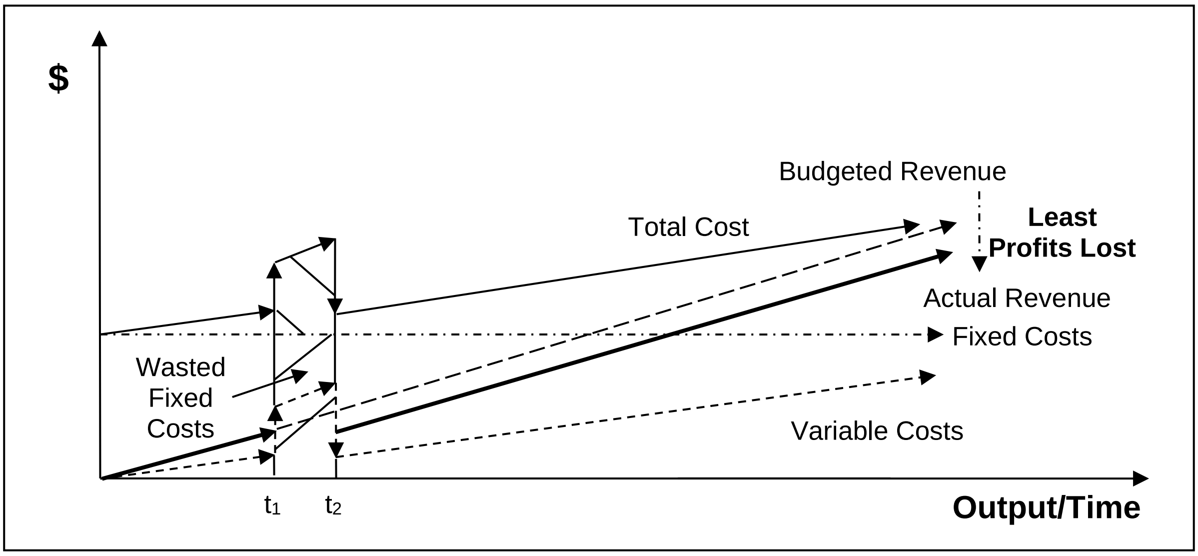

Figure 12.4—Effects on Profit by Reducing Both Chance and Consequence

Table 12.1 lists some of the current methods available to address risk. The methods are classified as chance reduction or consequence reduction strategies. Several observations arise when viewing each management philosophy. Consequence reduction strategies require a failure event to respond to. They use lagging indicators as triggers for action. They come into play at the end of the cause-and-effect path when no risk control options other than loss minimization and corrective actions are left. In contrast, chance reduction strategies focus on the early elimination of failure causes and on making business system changes to prevent or remove the opportunity for failure. They seek to eliminate and prevent the roots of risk. These methodologies work to improve business process success rather than improving failure detection methods. They expend time, money, and effort early in the cause-and-effect path to identify and stop problems so that the chance of failure is eliminated or at least drastically minimized.

Operating Risk = Consequence x Chance

Consequence Reduction Strategies	Chance Reduction Strategies

• Preventive maintenance
• Corrective maintenance
• Breakdown maintenance
• Predictive maintenance
  ○ Non-destructive testing
  ○ Vibration analysis
  ○ Oil analysis
  ○ Thermography
  ○ Motor current analysis
• Prognostic analysis
• Emergency management
• Computerized maintenance management system (CMMS)
• Root cause failure analysis
• Key performance indicators
• Risk-based inspection
• Operator watch keeping
• Financial accounting
• Stores and warehouses
• Maintenance engineering
	• Engineering and maintenance standards
	• Design out maintenance
	• Precision maintenance
	• Physics of Failure Reliability Strategy Analysis
	• Standardized operating procedures
	• Failure mode effect criticality analysis
	• Reliability growth cause analysis
	• Hazard and operability study
	• Hazard identification
	• Training and up-skilling
	• Quality management systems
	• Planning and scheduling
	• Continuous improvement
	• Supply chain management
	• Accuracy-controlled enterprise
	• DOCTOR
	• Total productive maintenance
	• More robust, durable materials
	• De-rate/oversize equipment

Reactive response to failure	*Proactive prevention of failure*

Table 12.1—Risk Management Processes and Methods

Both risk reduction philosophies are necessary for optimal protection. But a business with a chance reduction paradigm proactively prevents defects, unlike one with a consequence reduction focus, which will only fix defects. Those organizations that primarily apply chance reduction strategies set up their business to ensure a decreasing number of failures. As a result, they will get outstanding plant and equipment reliability and reap all the business benefits it brings.

Power Law Implications

Equations of the risk and loss type are known as *power laws* and take the general form $x = zy^n$, where ‘x’ is the outcome, ‘z’ is an influential factor, ‘y’ is a second influential factor, and ‘n’ is the exponent. For the standard risk formula ‘n’ is assumed to equal 1. Power laws have certain properties. For example, they are "scale-free." In the case of risk, consequences are not linear; although one incident may cost only a few dollars, when it happens another time, it could cost an immense sum. Power law outcomes are "typically a signature of some process governed by strong interaction between the 'decision-making' agents in the system."[1] This implies that risk does not arise entirely randomly; rather, it is affected by the decision makers present in interacting processes. These "influencers" change the chance of events toward the outcome. Situations that follow power laws have a higher number of large events occurring than in a normal distribution. For risk, this means that catastrophic events will occur more often than they would by pure chance. In power-law-mirrored events, a few factors have huge impacts, while all the rest have little effect. When it comes to risk situations, a small number of key factors influence the likelihood of catastrophe. Control these, and you will increase your chance of success.

The left side of Figure 12.5 is a graph of the risk formula on a normal linear-linear graph.[2] The risk plots as curves. You develop the risk curves by keeping the value of risk constant and then varying the frequency and the consequence. Anywhere on a curve is the same risk. ($1/event x 100 events/yr = $100/yr, or $100/event x 1 event/yr = $100/yr). The right side of the figure shows the log of the risk equation plotted on a $\log_{10}$-$\log_{10}$ graph. The fact that the base-10 logarithm of the risk equation plots as straight lines has special significance. It is an example of how power laws have an uncanny ability to reflect the real world. The insurance industry uses such curves to set insurance premiums because they closely represent what happens in human endeavours.

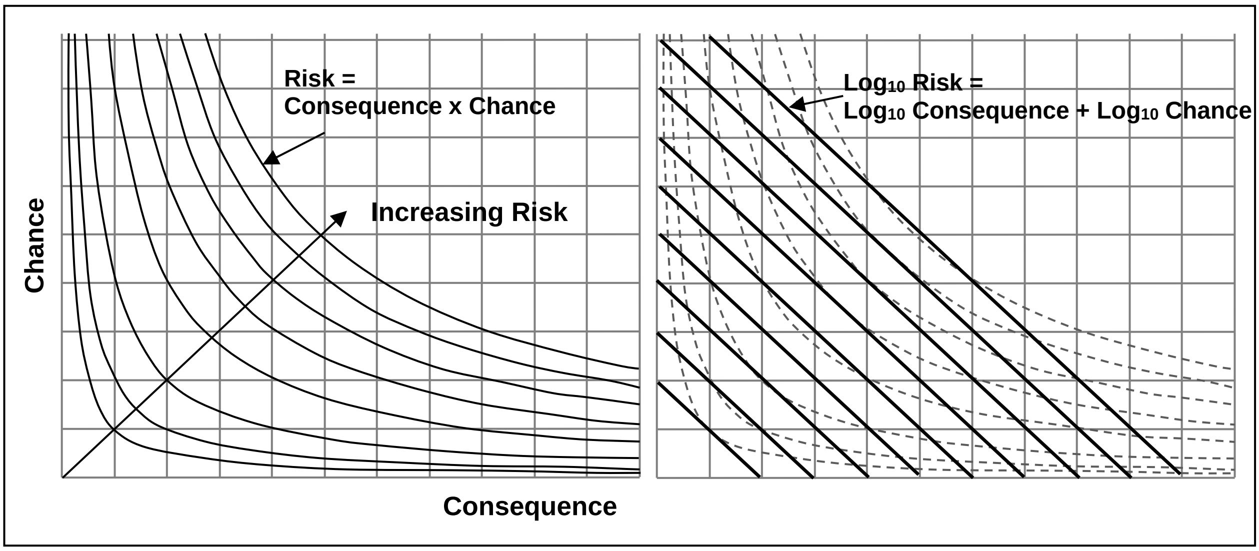

Figure 12.5—Risk Curves on a Linear Graph Become Risk Lines on a Log-Log Graph

Power laws that reflect the human world also tell us much about the situations from which they arise. Perhaps the most important understanding is the presence of "decision-making agents" within the system to which the power law applies. Philip Ball, in his book *Critical Mass*, points out that "physicists' long experience with power laws . . . leads them to believe that such laws are the universal signature of interdependence. A power law generally emerges from collective behaviour between entities through which local interactions can develop into long-range influences of one entity on another."[3] Our simple risk and loss equations now take on far greater and menacing implications.

Risk reflects the presence of "agents" working in an uncoordinated fashion within a system. The effects of these independent, random agents move through the system in unknown ways, and the results of their uncoordinated—and most likely perfectly justifiable—efforts are to increase risk. We now have another reason chance reduction strategies are more successful than consequence reduction strategies in reducing long-term organizational risk: chance reduction strategies work on controlling the systems in a business. They coordinate people and information, thereby removing the random influence of independent agents acting unwittingly to increase the causes of failure and loss. Gradually and continually, chance reduction strategies act to regulate and organize the efforts of these mysterious independent agents playing unscripted parts so that random actions and their effects are reduced and, eventually, removed. Chance reduction strategies are the opposite of consequence reduction strategies, which consider risk and failure normal. Instead, chance reduction strategies reduce risk forever. Because they strike at the random behaviour of the independent agents in a system, they align people, decisions, actions, and behaviours into an overarching system for achieving organizational outcomes using a specific, agreed-upon approach. Chance reduction strategies remove randomness and unplanned interactions from business systems.

It is in your organization's best interest, and it will consistently generate the most profit for the least amount of work, to focus on chance reduction strategies. Consequence reduction strategies are still important and necessary—once a failure sequence has initiated, you must find it quickly to minimize its effects so that you lose the least amount of money. But consequence reduction will not help your organization achieve world-class success because it expends resources. Only chance reduction strategies reduce the need for resources because they proactively eliminate failure incidents through defect elimination and failure prevention.

Similarity between Safety Incidents and Equipment Failures

Nothing is certain with risk; it changes with the circumstances. Some consequences of risk will be negligible, perhaps only an annoyance at worst, while others will be severe, and some will be catastrophic. Controlling risk demands that an organization develop the culture and habits that guarantee continuous, rigorous compliance with risk reduction practices, or else the chance of failure will rise over time as systems degrade to the point that the worst can happen.

Figure 12.6 updates the accident pyramid first developed by H. W. Heinrich from his early 1900's workplace safety research and published in his 1931 book, *Industrial accident prevention: a scientific approach*. It shows that for every serious injury, there are many minor incidents preceding it. The incidents are preceded by numerous events that are opportunities to become disasters. With enough opportunities, it is likely that one will cause serious injury at some stage.

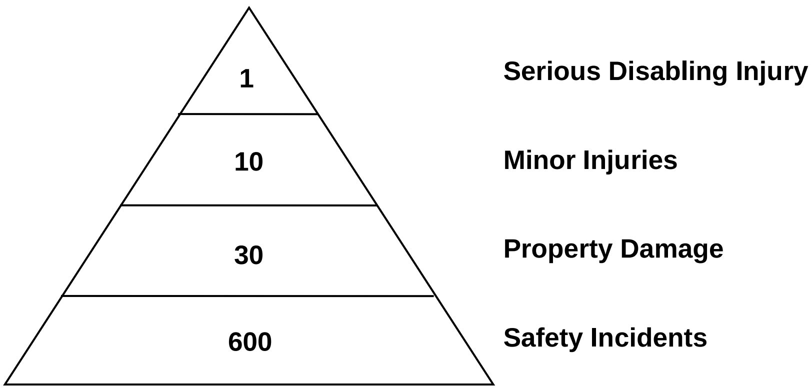

Figure 12.6—The Updated Heinrich Accident Pyramid

Analysis of historical industrial safety data not available in 1931 highlights that the safety pyramid is not completely representative of the modern workplace.[4] It correctly embodies the situation for minor injuries, where reducing the number of safety incidents leads to fewer minor injuries. But new data indicate that reducing the number of incidents does not correspondingly reduce the number of serious injuries. This is in line with the realization that risk is a power law and influenced by the decision-making elements within a system. Serious injuries are not accidental but rather the result of systematic failure caused by unintentional outcomes of uncoordinated decision makers within the system. Current best practice in workplace safety is to identify serious injury-causing situations before they happen and immediately act to stop them from ever leading to a real injury.

There are equivalent industrial data for the number of equipment failure opportunities needed before a serious production breakdown occurs. The concept of an equipment failure pyramid also applies, with many small errors at the bottom leading to greater consequences higher up. Figure 12.7 depicts a failure pyramid for equipment failures.[5]

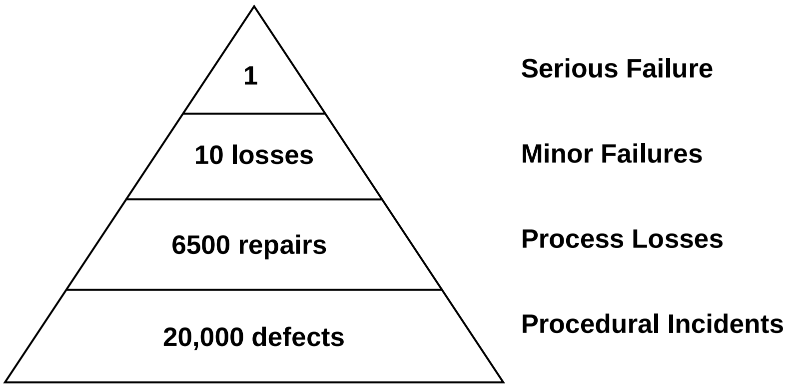

Figure 12.7—Equipment Failure Pyramid

The nature of risk, with independent actors all playing unscripted parts, changes the frequency with which situations arise. This implies that basing risky decisions on things not changing for long periods of time is fraught with danger. It is highly unlikely that frequency will remain constant because factors that are unknown and unknowable caused by decision-making agents are always altering the future. Risk's scale-less quality allows small concerns to cascade into major problems from the same events. What worked for us one day to prevent a failure may not work the next day because failure has found a different route. Our best protection against risk is to be vigilant in looking for its presence—look for its warnings, proactively eliminate the chance of defects, imagine the hazards, and remove them, and be prepared to respond with the right knowledge and skills when risk finds new ways into the organization.

As with the accident pyramid, the failure pyramid reflects a power law and stopping minor failures does not prevent catastrophic failures. Catastrophic loss is not controllable until the random decision-making elements in a system are regulated. Like minor safety injuries, minor equipment failures can be reduced by preventing the numerous and frequently occurring defects and errors that precede them. But to address catastrophic failures, you must intentionally imagine the worst outcomes and put into place measures to prevent them from ever happening. Physics of Failure Reliability Strategy Analysis uses that logic. Proactive measures are put in place throughout the life cycle to stop or lower the chance of risks arising later. You intentionally prepare your business by embedding standardized risk elimination and risk control practices in life-cycle processes so that randomness is restricted and situations that can precipitate disaster are eradicated.

There is one more concept regarding risk that is worth understanding and further justifies managing risk by chance reduction rather than consequence reduction. Serious risk events require many occurrences to coincide. Catastrophic events—those in which lives are lost or great costs result—do not often happen. A catastrophic loss requires the failure of a number of overlapping protective systems. A bad incident happens when situations align in such a way that the incident becomes possible: an opportunity for disaster now exists where it should not.

Example 12.1: The Titanic Disaster—When Gaps in Risk Protection Systems Align

In the early morning of April 15, 1912, the ship Titanic hit an iceberg during its maiden voyage from Southampton, England, to New York City. But the iceberg was not the root reasons the Titanic sank and caused great loss of life. The captain ran the ship at high speed during fog conditions in iceberg-prone seas. The ship was not fitted with sufficient safety boats for its entire complement of passengers and crew. The ship designers incorrectly believed that the ship was unsinkable because of their gross misunderstanding of the capability of the engineering design. The liner's rudder was undersize for the mass of the ship and it required a longer distance to change direction. The steel specified for use in building the vessel was prone to cracking.

On the night of the fateful disaster, all those failures, errors, and mistaken decisions aligned when the ship hit the iceberg and a great loss of life resulted. Like turning your two palms together with outstretched fingers, when the fingers align, a gap appears. So it was with the Titanic: the gaps in each layer of protection—operating procedures, safety practices, design assumptions, material selection—opened, and nothing was left to prevent a catastrophe.

The many small failures that happen in a business, such as misread numbers, lack of factual records, incomplete information, wrong material selection, lack of training, poor procedures and documents, shortcutting tasks, poor decision making, and many other similar blunders, will at some point in the future allow the gaps in protection to align and cause unwanted problems to drown a business and its people.

You can prevent failure incidents by providing many layers of protection and by completing the requirements for each layer properly. Use redundancy principles and add independent parallel proof tests so that fewer errors get through and cause problems later. Perhaps at a minimum, have three independent, unconnected layers of protection in place everywhere. More layers would be even better. For example, in a production environment, start with well-documented, accuracy-controlled procedures, then add thorough training and retraining and, finally, a comprehensive testing and audit process of workplace practices. A second example is a capital project to increase plant capacity. Start the design with detailed and clear operational, equipment reliability, and financial performance requirements written by the customer. During the design phase, test and prove that the proposals will deliver all of the requirements by using prototyping, modelling, or third-party review. The third layer is to conduct thorough and comprehensive DOCTOR analyses with the customer's involvement prior to purchasing plant and equipment.

Three-Factor Risk Analysis

The standard risk formula has two components: consequence and chance. The complete risk equation consists of three components: consequence, opportunity, and chance. The relationship is shown in the following formula:

Formula 12.2

Risk ($/yr) = Consequence ($) x [Opportunity (/yr) x {1 – Chance of Success at Each Opportunity}]

By replacing the "chance of success" with reliability, the formula becomes,

Formula 12.3

Risk ($/yr) = Consequence ($) x [Opportunity (/yr) x {1 – Reliability at Each Opportunity}]

Reduced to a simpler form, we can write risk and its three components as follows:

Formula 12.4

Risk ($/yr) = Consequence ($) x [Opportunity (/yr) x {1 – Reliability}]

The risk you carry is directly proportional to the size of the event consequence (bigger losses bring greater risk) and the number of opportunities for the event to occur (more opportunities to fail means more risk) and negatively proportional to reliability (higher reliability brings lower risk). Risk can be driven to zero if there are no consequences from a bad event, if there are no opportunities for a bad event to occur, or if there is perfect reliability, meaning that no failure can happen. You can lower risk by using three different techniques—consequence reduction, opportunity prevention, and reliability improvement. In Table 12.2, the two lists in Table 12.1 are broken down into the three risk categories: consequence, opportunity, and reliability. Having three components provides a wider perspective on your risk reduction options and lets you pick more effective solutions for a situation. With three-factor risk analysis, you open more possibilities to address a risk innovatively and simply, as your thoughts are not constrained by considering only two factors.

Opportunity elimination and reliability improvement are the prime risk control principles used in the Plant Wellness Way methodology. The use of consequence reduction techniques is not preferred because they do not remove risk, while you mistakenly believe that you have controlled it.

Operating Risk = Consequence of Failure x [Opportunity to Fail x (1 – Reliability at Opportunity)]

Consequence Reduction Strategies	Opportunity Reduction Strategies	Reliability Improvement Strategies
Strategies presume failure event occurs and act to minimise consequent losses	**Strategies prevent opportunities for the causes of a failure event to arise**	**Strategies reduce probability of failure initiation if opportunity is present**

• Preventive Maintenance
• Shutdown Maintenance
• Predictive Maintenance
  ○ Non-Destructive Testing
  ○ Vibration Analysis
  ○ Oil Analysis
  ○ Thermography
  ○ Motor Current Analysis
• Total Productive Maintenance
• Prognostic Analysis
• Emergency Management
• Computerised Maintenance Management System
• Key Performance Indicators
• Risk Based Inspection
• Operator Watch-keeping
• Financial Accounting
• Logistics, stores, and warehouses
• Total Defect and Failure Costing
• Maintenance Engineering
	• Physics of Failure Reliability Analysis
	• Accuracy Controlled 3T SOPs
	• Design and Operations Cost Total Optimised Risk
	• Reliability Growth Cause Analysis
	• Engineering / Maintenance Standards
	• Statistical Process Control
	• Degradation Management
	• Lubrication Management
	• Risk Analysis
	• Hazard and Operability Study
	• Hazard Identification
	• Failure Design-out Maintenance
	• Failure Mode Effects Analysis
	• Root Cause Failure Analysis
	• Precision Maintenance
	• Precision Operation
	• Training and Up-skilling
	• Quality Management Systems
	• Planning and Scheduling
	• Continuous Improvement
	• Supply Chain Management
	• Reliability Engineering
		• Precision Maintenance
		• Training and Up-skilling
		• Oversize / De-rate Equipment
		• More Robust, Durable Materials
		• Segregation / Separation
		• Controlled Atmosphere Environment e.g., +ve /-ve pressures, explosion proof atmosphere

Done to reduce the cost of failure	**Done to reduce the frequency of failure**	

Table 12.2—Risk Management Options with the Three Factors of Risk Control

FOOTNOTES

1. Philip Ball, *Critical Mass: How One Thing Leads to Another* (New York: Farrar, Straus and Giroux, 2005).

2. Peter Buckland, extract from “Boss, We Need a New Switchboard” presentation to the Australian Asset Management Council, 2005.

3. Philip Ball, *Critical Mass: How One Thing Leads to Another*, Page 324.

4. Miguel Angel Mariscal Saldaña, Susana García Herrero, Miguel Angel Manzanedo del Campo, and Dale O. Ritzel, “Assessing Definitions and Concepts within the Safety Profession,” *International Electronic Journal of Health Education*, vol. 6 (2003): 1–9.

5. Winston Ledet, *The Manufacturing Game* (Humble, TX: Ledet Enterprises, 2002).