Chapter 10: IONICS Process 2—Order Risks by Criticality

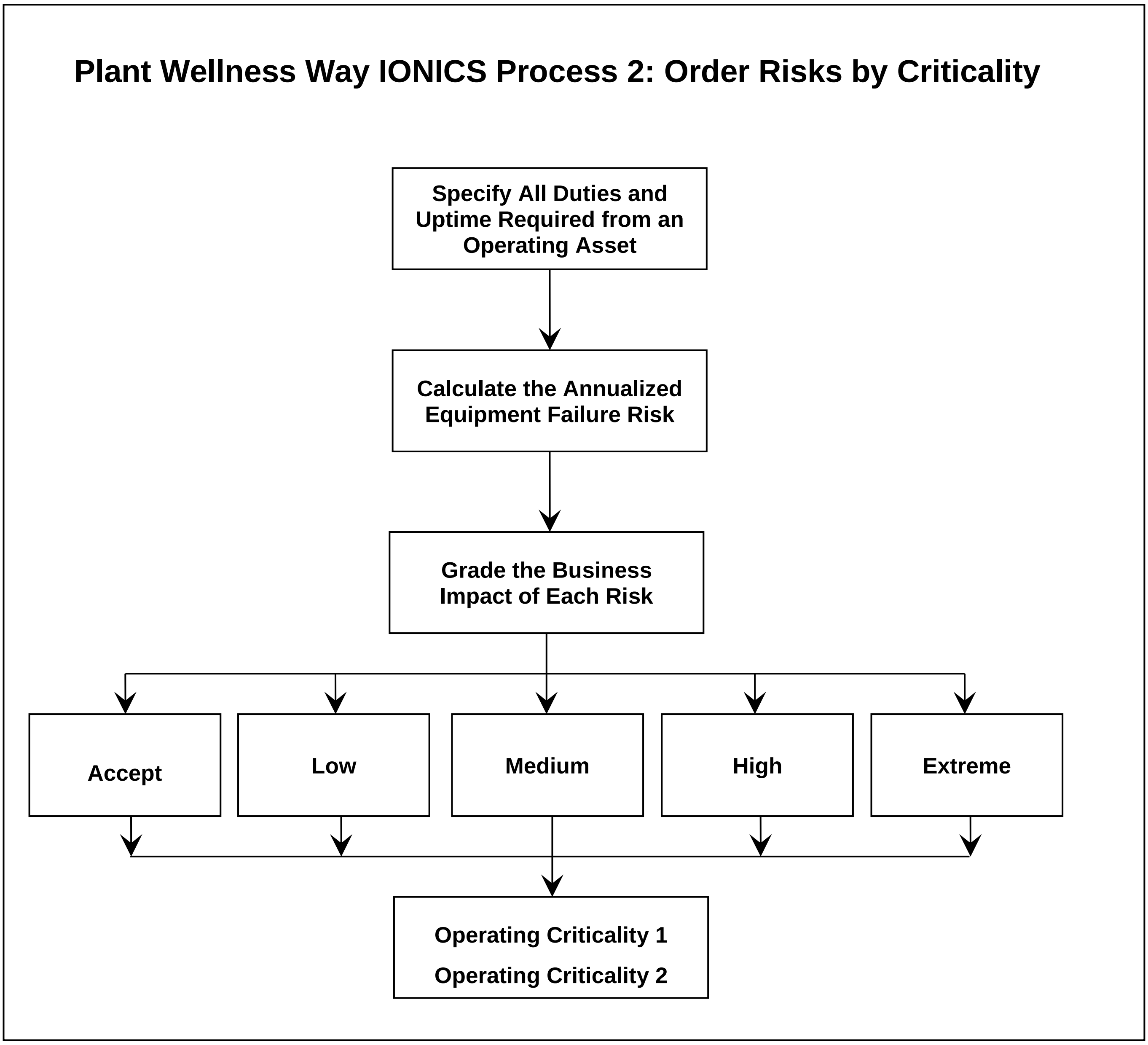

Figure 10.1—IONICS Process 2 Steps

Summary Description of Process 2: Rating Operating Risk

Not all your operating assets are equally important to your company's success. The grading of operating asset risk is known as *operating criticality analysis*. With it, you can match operating risk controls to the importance an asset has in your operation.

In Process 2, you follow the flowchart in Figure 10.1 to determine each asset's Operating Criticality 1 and Operating Criticality 2 values. Process 2 also requires you to develop an appropriate enterprise asset management policy and a supporting maintenance management policy. These policies articulate why physical asset management and maintenance are important to your business and give legitimate reasons for the use of business resources to implement them.

Specify the Asset Performance That Delivers the Operational Requirements

Why is an operating asset in your organization? What is its purpose in the business? For each physical asset, number it uniquely and give it a three- or four-word descriptive name that explains what it is and what it does for your operation—for example, "Finished Product Supply Pump" or "Workshop Overhead Gantry Crane." Specify the complete range of duties that each asset must perform when it is in service. Select a measurable indicator that represents each duty. Typically, this is a performance indicator that you use to determine the adequacy of the asset's operation. Record on the process map the required performance measures for each duty the asset must deliver.

Also note on the flowchart the service time that each asset must be available. For example, a stand-alone pump used to move product from a vessel to a storage tank must run when it is needed and deliver a desired flow at a minimum pressure using a motor of sufficient power. On the process map, the required functions and their minimum performance (e.g., pump flow, pressure) and the needed availability are noted. For a pump with service duty of at least 1,000 litres per minute flow rate, at 500 kilo Pascal (kPa) pressure, used three times a day for six hours duration each time, you would note “1,000 lt/min, 500 kPa, 3 x 6/24 hours” on the process map. This information helps determine the significance of an equipment item. If the pump cannot do its minimum duty as required during the working day, there will be consequential effects on production and throughout the business. Such service duty and availability information is needed for every item of equipment in your operation to clarify the purpose and use of each item.

Determine the Business Risk from Operating Failures

Operating criticality is the sum of all the risks that an item of equipment poses for your company. In the operating criticality determination, the TDAF cost calculated in Process 1 is the consequence value. It is multiplied by the yearly likelihood frequency of a failure to estimate the annualized financial loss you would suffer if the equipment failed.

The risk matrix you use must be calibrated to the impact that risk has on your business. You need to know what a low risk, medium risk, high risk, or extreme risk costs your business. Identify the risk boundary that your operation is willing to carry (i.e., the boundary between acceptable risk and low risk) before putting in place additional risk control strategies and actions. The sample 16 x 13 risk matrix provided in the spreadsheet accompanying this book is calibrated using a $10,000 per year risk boundary.

Assessing Operating Equipment Risk

In the Plant Wellness Way, operating criticality arises from component criticality; therefore, risk analysis is done at the equipment subassembly and component levels and not at the whole asset level. Because an asset fails when a critical part fails, you need to know the size of the risk that your organization carries from each component in your equipment. You then tailor the risk mitigations to reduce unacceptable component risk to an acceptable level while also aiming for no more than one failure in a period of three times the asset's service life. Those mitigations are the asset management, maintenance, and operating strategies that you will use in your company to create outstanding equipment reliability.

In order to understand the consequences of failed assemblies in your equipment, each asset is subdivided into its major assemblies. If a major assembly contains substantial numbers of individual equipment, these are further divided into subassemblies and key components. The annualized sum of failures for subassembly critical components is used for the likelihood frequency.

A business makes money if a risk is prevented for less than the risk's total consequential cost. The greatest opportunity for a business to reduce risk for least cost is to identify the methods, systems, and practices that prevent a risk or minimize the chance of a risk arising and then implement them with energy and vigour across the organization. Maintenance is one way to reduce the risk of equipment failure, but it is typically used as a consequence-reduction strategy in response to failure. There are also numerous engineering and operational choices, which are usually more cost-effective over the equipment life cycle than maintenance because they are chance reduction strategies that stop failures from starting in the first place.

Plant and equipment risk analysis applies the risk formula using historical financial and failure information for the asset under review. Table 10.1 shows typical column headings of a risk assessment spreadsheet used to gauge current operating equipment risk.

Ref No.	**Equip ment Tag No.**	**Equip Descrip tion**	**Failure Events or Causes**	**TDAF Cost Consequence of Failure ($)**	**Years Equipment in Service or Expected**	**No. of Item Historical Failures at This Site or Expected**	**No. of Annualized Failure Events Due to Cause**	**Likelihood of Failure Event (/Yr)**	**Estimated Current Risk ($/Yr)**
1	2	3	4	5	6	7	8	9	10

Table 10.1—Typical Risk Calculation Spreadsheet Layout

The “Equipment Tag No.” (Column 2) is the identifying number given to each item of equipment at a site. Every tag number is included—machinery, electrical equipment, instrumentation, piping, even the buildings and each functional area in a building—to determine a site’s total risk. Additional columns are added when subassemblies or components need to be individually identified.

The “Equipment Description” (Column 3) is the official descriptive name for the equipment or is subassemblies. List the assemblies, subassemblies, and parts that have failed in the past or have a fair possibility of failing in future.

“Failure Events or Causes” (Column 4) are the many separate ways in which an item of equipment has failed or could fail.

The “Cost Consequence of Failure” (Column 5) is the TDAF cost impact of an item’s failure.

“Years Equipment in Service or Expected” (Column 6) is the number of years the item has been in use and is expected to be in use. For new equipment, the expected years in-service is used.

For existing equipment, it is the sum of life to date plus expected years remaining in service. Work in years to an accuracy of a calendar quarter.

The "No. of Item Historical Failures at the Site or Expected" (Column 7) is determined for each identified failure event or cause by looking at the equipment history in the operating records and maintenance management system. If actual site failures are not available, then the industry average adjusted for the on-site reliability culture is adopted. If there is a good reliability culture and standard industry maintenance and care practices are applied well, use the industry average as the event frequency; in a poor reliability culture, assume a substantially worse outcome.

The "No. of Annualized Failure Events Due to Cause" (Column 8) is calculated by dividing Column 7 by Column 6.

The "Likelihood of Failure Event" (Column 9) is a probability assessment using the frequency of historical events. It is also described using the terms listed in Table 10.2 developed from international risk management standards and industry guides.[1, 2]

In the last column is the item's "Estimated Current Risk" calculated by multiplying the values from Columns 5 and 9 using the standard risk formula—Formula 9.1.

Descriptor	**Description**	**Indicative Frequency (Expected to occur)**	**Actual Failures per Year (Historic evidence basis)**	**Likelihood of Failure per Year (Opportunity for failure basis)**	
				Opportunities	Probability of Failure
Certain	Failure event will occur at this site annually or more often	Once a year or more often	1/year or more	Count every time the situation arises when a failure event could occur	1 if failure results every time the situation arises
Likely	Failure event regularly occurs at this site	Once every 3 years	1 in 3 years = 0.33/year		0.1 if failure results 1 in 10 times the situation arises
Possible	Failure event is expected to occur on this site	Once every 10 years	1 in 10 years = 0.1/year		0.01 if failure results 1 in 100 times the situation arises

Unlikely	Failure event occurs from time to time on this site or in the industry	Once every 30 years	1 in 30 years = 0.033/year		0.001 if failure results 1 in 1,000 times the situation arises
Rare	Failure event could occur on this site or in the industry but doubtful	Once every 100 years	1 in 100 years = 0.01/yr		0.0001 if failure results 1 in 10,000 times the situation arises
Very Rare	Failure event hardly heard of in the industry; may occur but under exceptional circumstances	Once every 1,000 years	1 in 1,000 years = 0.001/year		0.00001 if failure results 1 in 100,000 times the situation arises

Table 10.2—Determining the Likelihood of Equipment Failure at a Site

Determining the likelihood of failure is fraught with uncertainty. The opportunity for failure may rise often but never go to conclusion. Counting historical failures is easy because there are records. But counting an opportunity for failure that does not progress to a failure is open to speculation. For example, one opportunity for failure is overload upon equipment start-up. The likelihood of failure for a part known to fail because of high-stress overload during start-up can be calculated using Formula 10.1. The opportunity for this failure is a count of the average number of starts between failures. The likelihood of failure formula is as follows:

Formula 10.1

$$\text{Likelihood of Failure} = \frac{\text{No. of Failures}}{\text{Average Number of Starts between Failures}}$$

For an operation running continuously with 10 starts a day and failures averaging every six months, or twice a year, the likelihood of failure is calculated as follows:

$$\text{Likelihood of Failure} = \frac{\text{1 Failure}}{\text{1,825 Starts}} = 0.000556$$

With a TDAF cost of failure of $25,000, the risk calculated using Formula 9.2 is as follows:

Risk = Consequence ($) x [No. of Opportunities (/yr) x Probability of Failure]

= $25,000 x [3,650 x 0.000556] = $50,000/yr

The $50,000 annual risk estimated by first finding the probability is the same as that estimated using the standard risk formula ($25,000 x 2/yr). When failures have happened, it is easier to count the average failures per year from historical evidence and use that number in the standard risk equation. Historical failures are used because they already reflect the risk present in an operation. Future failure rates will remain the same as in the past until better risk management strategies are put in place. You use the opportunity for failure approach in Formula 10.1 if you know how often a failure situation arises. But if the number of opportunities is uncertain, use the historical average of failures per year for the site.

The Estimated Current Risk shown in Table 10.1 is the yearly cost for the existing risk in the business. The value is used to rate and gauge the size of a risk and compare it with others. For those risks that a business does not want to carry mitigations are put in place to eradicate or reduce them to acceptable levels if they cannot be eliminated.

Risk Assessment and Risk Mitigation Templates

A Risk Identification and Assessment Template can be used to find and list the operating risks to each equipment, assembly, and subassembly. Identifying failure events and grading their risks can be done using Table 10.3. Alternatively, a spreadsheet can be developed to replace the template. For equipment and assemblies being assessed, a calibrated risk matrix is used to categorize the consequence, likelihood, and risk level for each risk event. In the Plant Wellness Way, an operating asset's risk assessment is done using the "Operating Criticality" spreadsheet accompanying this book.

EQUIPMENT OR ASSEMBLY	EVENT OR FAILURE *What can happen?*	SOURCE *How can this happen?*	IMPACT *of event happening*	CURRENT CONTROL STRATEGIES *and their effectiveness* (A) – Adequate (M) – Moderate (I) – Inadequate	CURRENT RISK LEVEL			ACCEPTABILITY (A/U)
					LIKELIHOOD	CONSEQUENCE	CURRENT RISK LEVEL	
1	2	3	4	5	6	7	8	9

Table 10.3—Risk Identification and Assessment Template

A Risk Treatment Schedule and Action Plan Template can be used to identify actionable activities to reduce risk. The template in Table 10.4 is used to list actions to mitigate the risk and to judge their effectiveness.

EQUIPMENT OR ASSEMBLY RISK	POTENTIAL TREATMENT OPTIONS	COSTS AND BENEFITS	TREATMENTS TO BE IMPLEMENTED (Y/N) *and their effectiveness* (A) – Adequate (M) – Moderate (I) – Inadequate	RISK LEVEL AFTER IMPLEMENTATION			RESPONSIBLE PERSON	TIMETABLE *to implement*	MONITORING *strategies to measure effectiveness of risk treatments*
				LIKELIHOOD	CONSEQUENCE	TARGET LEVEL			
1	2	3	4	5	6	7	8	9	10
		FINAL Cumulative Risk Level after Treatment							

Table 10.4—Risk Treatment Schedule and Action Plan Template

At the end of the risk assessment and review, all the risk mitigation actions for an asset become part of that asset's risk management plan.

Performing an Operating Criticality Analysis

Table 10.5 is an example of a Plant Wellness Way operating criticality review.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	**Operating Criticality 1 and 2 Analysis**																			
2	**Ref No.**	**Equipment Tag No.**	**Equip ment Description**		**Parent Assembly**		**Subassembly**		**Components**	**Risks: Possible Causes of Failure**	**Worst Effect of Failure**	**Operating Criticality 1 = TDAF Cost of WorstFailure ($)**	**Equip ment Past Years of Service**	**Equipment Remaining Years of Service**	**Likelihood of Failure Event** (by risk matrix)	**Operating Criticality 2 by Risk Matrix Rating**	**Number of Historical Failures to Equipment in Lifetime**	**Annualized No. of Failure Events Due to Cause**	**Operating Criticality 2 = Sum of Risk Values**	**Comments**
3												**($)**		**(Yrs)**		**(L, M, H, E)**		**(/Yr)**	**($/Yr)**	
4	1	TRN-01	250 KVA Power Supply		Transformer							**$10,000,000**							**$122,000**	**NOTE: Death is possible**
5						1	Tank with Fins			Leakage	Downtime	$100,000	25	25	Unlikely	L	1	0.02	$2,000	$25,000 per hour TDAF cost; minimum 4 hours if power is
6						2	Tap Changer			Arcing	Downtime	$200,000	25	25	Likely	H	3	0.06	$12,000	Minimum 8 hours if power is removed
7										Mechanical Damage	Downtime	$200,000	25	25	Possible	M	2	0.04	$8,000	Minimum 8 hours if power is removed
8						3	Oil			Oil Degradation	Downtime	$300,000	25	25	Possible	M	2	0.04	$12,000	Minimum 12 hours if power is removed
9						4	HV Termination Bushings			Poor Connections	Arcing, Downtime	$2,000,000	25	25	Unlikely	H	1	0.02	$40,000	Minimum 1 month lost for repair (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
10						5	Insulation			Cellulose Degradation	Downtime	$200,000	25	25	Possible	M	2	0.04	$8,000	Minimum 8 hours if power is removed
11						6	Core			Mechanical Damage	Efficiency Loss	$2,000,000	25	25	Rare	M	1	0.02	$40,000	Minimum 2 weeks lost for repair
12						7	Windings			Windings Short-Circuit	Fire	$10,000,000	25	25	Unlikely	E	0	0.00	$0	Minimum 1 month lost for repair (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
13						8	Oil Conservator			Leakage	Downtime	$500,000	25	25	Rare	L	0	0.00	$0	Minimum 8 hours if power is lost
14	2	SWB-01	Infeed Switchboard		Switchboard							**$2,000,000**							**$278,000**	**Note: Death is possible**
15						1	Panel			Fire	Fire, Downtime	$2,000,000	25	25	Rare	M	0	0.00	$0	Complete rebuild of switchboard takes 2 weeks (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
16										Liquid Ingress	Short-Circuit	$200,000	25	25	Unlikely	M	1	0.02	$4,000	Minimum 8 hours if power is lost
17										Vehicle Impact	Downtime	$200,000	25	25	Unlikely	M	1	0.02	$4,000	Minimum 8 hours if power is lost
18						2	Bus Bar Connections			Improper Connection	Fire, Explosion	$2,000,000	25	25	Unlikely	H	1	0.02	$40,000	Complete rebuild of switchboard takes 2 weeks (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
19						3	Panel Connections			Loose Cable Clamp Bolt	Fire, Downtime	$2,000,000	25	25	Unlikely	H	2	0.04	$80,000	Complete rebuild of switchboard takes 2 weeks (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
20										Poor Cable Crimping	Fire, Downtime	$2,000,000	25	25	Possible	E	2	0.04	$80,000	Complete rebuild of switchboard takes 2 weeks (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
21						4	Drive Rack			Dust from	Downtime	$100,000	25	25	Possible	H	2	0.04	$4,000	
22										Poor Assembly	Downtime	$100,000	25	25	Possible	L	2	0.04	$4,000	$25,000 per hour TDAF cost; minimum 4 hours if power is
23										Rusted into Place	Downtime	$100,000	25	25	Rare	A	1	0.02	$2,000	$25,000 per hour TDAF cost; minimum 4 hours if power is lost
24						5	Motor Starter			Overload	Downtime	$200,000	25	25	Possible	M	5	0.10	$20,000	Rebuild motor starter will take 2 days
25										Short-Circuit	Downtime, Fire	$2,000,000	25	25	Possible	E	1	0.02	$40,000	Complete rebuild of switchboard takes 2 weeks (Note: If a life is lost, add $5,000,000 to the TDAF cost for each person)
26	3	PMP-01	Circulation Pump-Set																	
27				1	Power Cable															
28				2	Electric Motor															
29						1	Terminal Block													
30						2	Motor	1	1 Frame											
31								2	2 Base Plate											
32								3	3 Hold-down Bolts											
33								4	4 Pedestal											

Sheet1

Table 10.5—Operating Criticality 1 and 2 Analysis

The analyst who does the risk assessment needs to be a person with engineering knowledge of the asset and the ways in which its components can fail. When necessary, gather a team of subject matter experts to ensure the completeness and thoroughness of the analysis. Each column heading in the spreadsheet is addressed as accurately as possible during the analysis. When accurate information is not available, adopt the considered recommendations of the subject matter expert team.

The Problem with Standard Equipment Criticality

The rating of an equipment item at a certain criticality is the result of making informed decisions about the frequency and consequences of a failure. These opinion-based choices are open to misunderstandings and preferences. Because risk analysis involves subjective decisions founded on experience and familiarity with consequences, it is possible that a person's knowledge is not deep and broad enough to make the better choice. They may be overly conservative and make an item high criticality when it is not, thereby causing maintenance costs to rise from unnecessary use of resources. Worse is a low criticality rating when it should be high and thereby chancing disastrous failure.

In the author's field experience, standard criticality rating is done too superficially to appreciate the intricate nature of equipment risks in a business. Important equipment gets mistakenly rated at a lesser risk than it should be and therefore does not get adequate maintenance and care. When a wrong analysis is done, the risk is not controlled well enough, and the equipment continues to fail. Standard equipment criticality risk rating allows people to make guesses, whereas a Plant Wellness Way operating criticality rating requires facts about all the risks your plant causes.

Table 10.6 is an example of a standard equipment criticality rating for a rear-drive family car. It uses the traditional operational impact approach, in which keeping the car in operation is important, but no consideration is given to the total effect of a failure on the family.

Standard Risk Rating for a Rear-Drive Family Car						
Component	**Subcomponents**	**Failure Effects**			**Criticality by Risk**	**Maintenance and Care Required**
		Unusable	Causes Difficulty	No Concern		
Engine						
	Fuel System	Y			High	Regular Service
	Crank and Pistons	Y			High	Regular Service
	Engine Block	Y			High	Regular Service
	Cooling System	Y			High	Regular Service
	Oil System	Y			High	Regular Service
	Ignition System	Y			High	Regular Service
Gearbox						
	Input Shaft	Y			High	Regular Service
	Internal Gears	Y			High	Regular Service
	Output Shaft	Y			High	Regular Service
	Casing	Y			High	Regular Inspection
Drive Train						
	Drive Shaft	Y			High	Regular Inspection
	Differential	Y			High	Regular Service
	Axels	Y			High	Regular Inspection
	Wheels		Y		Medium	Regular Inspection and Rotation
Body						
	Dash Display		Y		Medium	Regular Inspection
	Indicator Lights		Y		Medium	Regular Inspection
	Lights		Y		Medium	Regular Inspection
	Windows		Y		Medium	Regular Inspection
	Doors		Y		Medium	Regular Inspection
	Panels			Y	Low	
	Chassis		Y		Medium	Regular Inspection
Suspension						
	Shock Absorbers	Y			High	Replace at End of Life
	Springs	Y			High	Replace at End of Life
	Frame		Y		Medium	Regular Inspection

Table 10.6—Standard Risk Rating for a Rear-Drive Family Car

The standard methodology produces maintenance and operating recommendations to address the perceived risks in the use of the car. Sure, it's a criticality analysis, but its value for sound risk reduction decision making is low. There is no evidence that the mitigations are correctly matched to the risk or that they will adequately control the risks to the family's satisfaction. The risks are not quantified as a cost that the family will pay, so there is no understanding of the money they will lose from the problems they will suffer when the car fails.

Table 10.7 shows a criticality rating for the family car using the Plant Wellness Way operating criticality method. The criticality analysis starts by identifying the TDAF costs of each major assembly and its main subassemblies. It is also useful to note the length of time needed to recover from an incident. Often, the opportunity loss caused by the downtime is a more critical factor than the cost of the repair. For this example, the risk matrix in Table 5.3 is recalibrated at $20 for "Insignificant," increasing by multiples of 10 in the subsequent columns. The risk matrix is used to determine the risk level and a total risk number. The fuel system, for example, has a moderate cost of $1,500 if it fails (nearest consequence value is 3) and a rare chance of failure (frequency value 2), for a risk number of 5, corresponding to a medium risk. It is an event a family would not want to suffer.

Plant Wellness Way Risk Rating for a Family Car

Assembly	Subassembly	TDAF Cost Rating			Criticality By Risk		Criticality by TDAF Cost	Required Operating Practice	Required Maintenance
		System Loss Cost ($)	Assembly Loss Cost ($)	Time to Recover (days)	Rank	Number			
Engine		6,000		21	Medium	6	6,000		
	Fuel System		1,500	3	Medium	5	1,500	Monitor Operation	Regular Service of Parts
	Crank and Pistons		3,000	21	Medium	5	3,000	Monitor Operation	Replace at End of Life
	Engine Block		3,500	21	Medium	5	3,500	Monitor Operation	Replace at End of Life
	Cooling System		1,500	5	Low	5	1,500	Monitor Operation	Regular Service of Parts
	Oil System		1,000	5	Low	5	1,000	Monitor Operation	Regular Service of Parts
	Ignition System		1,500	5	Low	6	1,500	Monitor Operation	Regular Service of Parts
Gearbox		5,000		28	Medium	5	5,000		
	Input Shaft		1,000	5	Low	4	1,000		Regular Service of Parts
	Internal Gears		2,500	28	Low	4	2,500		Regular Service of Parts
	Output Shaft		1,500	5	Low	4	1,500		Regular Service of Parts
	Casing		3,000	28	Low	4	3,000	Monitor Operation	Regular Inspection
Drive Train		2,500		28	Medium	7	2,500		
	Drive Shaft		1,000	14	Low	4	1,000	Monitor Operation	Regular Inspection
	Differential		2,500	28	Medium	5	2,500		Regular Service of Parts
	Axel x 1		1,500	14	Low	4	1,000		Regular Inspection
	Wheel x 1		1,000	3	Medium	5	1,000	Monitor Operation	Regular Inspection
Car Body		20,000		54	High	8	20,000		
	Dash Display		4,000	28	Medium	5	4,000	Monitor Operation	Regular Inspection of Condition

	Electrical System		4,000	14	Medium	6	4,000	Monitor Operation	Regular Inspection
	Lights		1,000	5	Medium	6	1,000	Monitor Operation	Regular Test
	Window x 1		1,000	5	Medium	6	1,000	High Driving Skills	Regular Inspection
	Door x 1		2,000	14	Medium	6	2,000	High Driving Skills	Regular Inspection for Corrosion
	Panel x 1		3,000	14	Medium	6	3,000	High Driving Skills	
	Chassis		15,000	54	High	7	15,000	High Driving Skills	Regular Inspection for Corrosion
Suspension		8,000		28	Medium	5	8,000		
	Shock Absorbers		1,000	3	Medium	4	1,000	Monitor Operation	Replace at End of Life
	Springs		1,000	5	Medium	3	1,000	Monitor Operation	Replace at End of Life
	Assembly x 2		5,000	28	Medium	5	5,000	High Driving Skills	Regular Inspection for Damage

Table 10.7—Plant Wellness Way Risk Rating for a Family Car

In the table, there is a TDAF cost of $20,000 for damage to the car body—a substantial cost to the owner. It is also the highest risk number because road accidents are possible (frequency value 4). Damage to the chassis from road accidents or running over curbs comes next at $15,000 to repair. Broken suspension cost of $8,000 is third. The engine, at $6,000, is not the most expensive failure, but there is an annoying time delay in getting the car back on the road if vital engine components are damaged. The standard equipment criticality rating would not have produced such a thorough understanding of the failure consequences to the organization (a family). Having a real cost of assembly and component failure provides great insight into the true impacts that a risk has on an organization.

The biggest risks come from car accidents and from uncaring drivers who do not respect the vehicle. The best strategy to minimize risk is to ensure that drivers have high driving skills along with good road sense and attitudes. They could be sent to a defensive driving school to learn accident-evasion techniques. The mechanical and electrical equipment in the car is best protected from failure by educating drivers about how a car and its parts work and by conducting regular servicing and inspection. The organization maintaining the car will need to do a wide range of inspections. The selection of the maintenance provider should first be based on comprehensiveness and competency of the service it provides. Minimizing the cost-of-service work is important, but it is secondary to ensuring the quality of work done on the family car so that it is always roadworthy and safe to drive.

Using TDAF costs for determining component criticality shows that the failure cost of the car's structural parts is actually very expensive for the family. These parts received little attention in the standard criticality rating because a low frequency implied few failures. People mistakenly consider them of lower importance because of their low risk. The TDAF cost approach warns that although the equipment may not fail often, when it does, it will be expensive and have destructive consequences for the owner. By reviewing the cost of failure independently of the chance of the failure, the TDAF cost equipment criticality approach makes clear just how bad each failure would be if it happened.

The Plant Wellness Way equipment criticality process also determines where responsibility lays for protecting equipment from harm. By the type of failure, it is clear whether the operator or the maintainer needs to conduct mitigation. Control of the risk by proper operation, by proper maintenance, or by reengineering becomes self-evident. In the car example, only the driver (the operator) can prevent an accident. Only the driver can steer the car so that it does not go over a curb and destroy the suspension. The maintainer cannot prevent such failures. The maintainer gets involved only for preventive maintenance or after the car is damaged. The complete risk management plan for family car involves having a skilled operator (the driver) who knows how to drive well and does not put the car into situations that risk damage. It includes the driver noticing when things are not working properly and reporting them for maintenance before a full failure develops. There will also be regular servicing of the car and its systems by a competent mechanic.

Knowing the full cost of a failure lets you pick effective risk control strategies, helps validate additional training, justifies the purchase of risk monitoring equipment, and requires making changes to procedures to ensure that risk mitigations are done. All these wise business risk management actions are not justifiable with the traditional equipment criticality rating method, which misrepresents risk and leaves out the full range of their impacts.

The outcomes from Process 2 are the Operating Criticality 1 and Operating Criticality 2 values. In Process 3, the unacceptable risks found in Process 2 are eliminated by using appropriate mitigations throughout the life cycle. Otherwise, they are controlled to acceptable risk levels with suitable engineering, operating, and maintenance actions.

FOOTNOTES

1. "ISO 31000:2009—Risk Management," accessed at http://www.iso.org/iso/home/standards/iso31000.htm, August 3, 2015.

2. Richard M. Robinson et al., *Risk and Reliability: An Introductory Text*, 7th ed. (Melbourne, Australia: R2A, 2007).