

Chapter 6: IONICS Process 1—Identify Business and Operational Risks

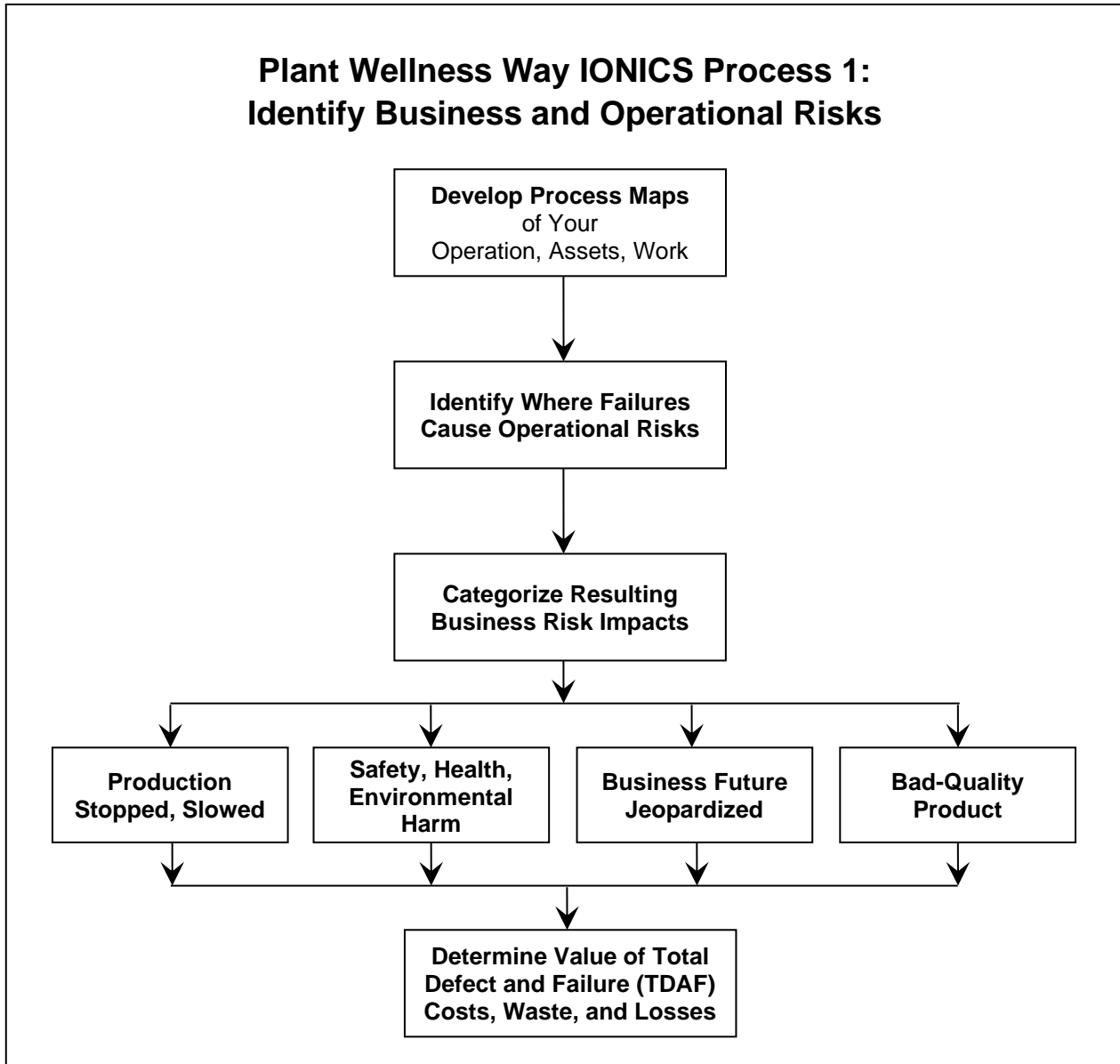


Figure 6.1—IONICS Process 1

The climb to the peak of reliability excellence needs a sure path to the top. The first step to take is for an organization to choose to make the ascent. Then you use IONICS to develop a believable, properly resourced plan to climb to the heights of world-class reliability. That is what you will have once you complete the six-step IONICS process. Your ascent up the Plant Wellness Way begins with Process 1, which is depicted in Figure 6.1.

Summary Description of Process 1: Risk Identification

In Process 1, you gauge the total business-wide costs of the harm, waste, and losses incurred when your operating plant and equipment fail. If the costs are unacceptable, you must eliminate the risks or, at the very least, put in place effective risk preventions.

Develop Process Maps

Start by making a process map to illustrate what you are analyzing. For example, to analyze an equipment item for reliability improvement, lay out its assemblies in logical operating order. If you are analyzing a job with the intent to improve it, draw a flowchart of all its sequential tasks. When investigating a production line, the process map shows the individual production steps from beginning to end in order of product flow, starting with the raw materials supplied and progressing through the production process to the outputs that the business provides.

The process map is the foundation document for removing operational risk. It shows the design logic of the process, plant, or workflow. Simple rectangles joined together by arrows across the page provide a visual tool for understanding how a system, process, or workflow operates. Using a process map helps you do a more complete, more detailed job of analyzing weaknesses and identifying business and operating risks. It allows you to see interconnectivity within and across processes and the impact of a step's reliability on process performance. Later, you will use the process map to design a better solution and to create key performance indicators to monitor and measure results. A process map helps you explain to others the improvements that are needed, why they will be effective, and how they will be implemented. Examples of process maps can be found in the

preceding chapters as well as in the following pages. An example of a process map for a maintenance job is shown in the “Job Process Map” worksheet in the spreadsheet accompanying this book.

Identify At-Risk Process Steps and Assets

Using the process map, create a spreadsheet in which to record all the items shown in the flowchart. For example, in the case of a production line, enter each production asset, in order of use, into the spreadsheet. When analyzing an asset to improve its performance, list its subassemblies. For analysis of a subassembly, list all of its parts in sequence. For a job, list the individual work tasks in the order in which they are done. Leave nothing out of the list. You will not get protection from failure if items are not identified for analysis. Give each item in the list its own row in the spreadsheet and a unique number. The spreadsheet will later be expanded for other uses. An example of such a layout for equipment items is the “Operating Criticality” worksheet in the spreadsheet accompanying this book.

Categorize the Effects of Risk for Each Step

When analyzing a process or workflow, take each step listed in the worksheet and identify how it could fail in service. Write down failure or error events that could produce a loss or cost to your business. A failure is any incident or problem that affects quality, production rate, health, safety, the environment or causes downtime. Record the known failures and the possible causes (i.e., those that might happen during the operation’s lifetime) for each item. You can start creating this list from your memory of past events and knowledge of the situation. Finally, review the Physics of Failure Factors to check for other possible risks to address. Next to each cause, indicate its effect on the operation’s performance, people, and environment. If there are no operational risks whatsoever across the life cycle for a flowchart step, the analysis is taken no further because there are no risks to be addressed.

Analyzing equipment operating risk necessitates finding all of the critical working parts on the bill of materials and identifying the many ways that each one could fail in your operation. Known failure events will be recorded in the maintenance or operating history and recollected from peoples' memories. Finally, review each part using the Physics of Failure Factors mechanism guide words to check whether there are other possible risks to the equipment.

Estimate the Total Defect and Failure Costs

For each failure cause, record an estimated total defect and failure cost for the worst-case scenario. The TDAF cost is the company-wide cost surge that a failure causes the business. The final value can total far more than the cost of maintenance and lost production. If you cannot calculate the full TDAF cost using the method described in this book and the example TDAF cost worksheet, then calculate the direct costs of maintenance for the repair (maintenance labor, parts, outside services, and overhead) and multiply that value by 10 for continuous process operations and by 5 for batch processes. This factored cost gives a conservative lower value of the total surge costs and losses that each plant and equipment failure cause your business.

The TDAF cost is the loss consequence value used in the risk formula. As you work through the Plant Wellness Way life-cycle asset management strategy analysis, you select risk controls to reduce total operating risk to an acceptable level on the risk matrix—ideally, to less than one failure in three service lifetimes. It is presumed that all failure events will happen until you select mitigations to prevent them. Given enough time and opportunity, the severest possible event can happen in your operation. When a person could die in a failure event, indicate that possibility and the cost of their death to the business in the Comments field of the equipment item being analyzed. An important outcome from the analysis is to deliver strategies and actions that will keep your people safe.

Start with a Process Map of the Situation

Whether you are improving a work process, a production line, or an equipment item, the process map is a “picture” of the logic of how a thing works. Drawing a process map of a situation lets you more fully understand its operation and find its weaknesses. A process map lets you ask good questions that allow you to understand problems and make useful risk reductions. Mapping the logic of a situation is the way to start all equipment reliability and business process improvement. This is necessary so that you can design more successful solutions.

A process map of an industrial operation, a job, or a plant item allows reliability improvement principles to be used to reduce the chance of its failure and to lift the chance of its success. With a process map, Series Reliability Property 1 (see Chapter 1) is applied to find new solutions to mistake-proof each step so that errors do not lead to defects and failures. With a map of your process steps, you can investigate the best way to include parallel activities to lift each step’s reliability. A process map also lets you use Series Reliability Property 2 to find ways to remove steps and simplify a process. Take the time and make a good effort to draw your process maps in detail so that you will be more successful.

Business Process Maps

Business process flowcharts start with a high-level overview of the key functions in the business and how they are interconnected. Each box in the high-level map will have its own process and subprocesses to be drawn. Process maps of the lower process levels are also needed in order to see the full details and complexity of how a business operates. You’ll need to create a process map at the location and level of the business that you are investigating.

Figure 6.2 is an example of a high-level process map of the steps in an operating asset life cycle. Within each box are other processes that collectively achieve the high-level step’s purpose. The life-cycle process map immediately shows two types of risk: it’s a series arrangement across time with an immense number of interactions and choices, and it’s got people working in it, so human error will be a major cause of failures. Without a flowchart, it would be difficult to imagine the whole operating life cycle and hopeless to decide where to focus in order to find the weaknesses in the processes. Next you make detailed process maps for the step of interest down to the level that you need to investigate. For example, in the case of the “operate” phase, you would develop flowcharts of the existing engineering, operations, procurement, storage, and maintenance processes and their interactions.

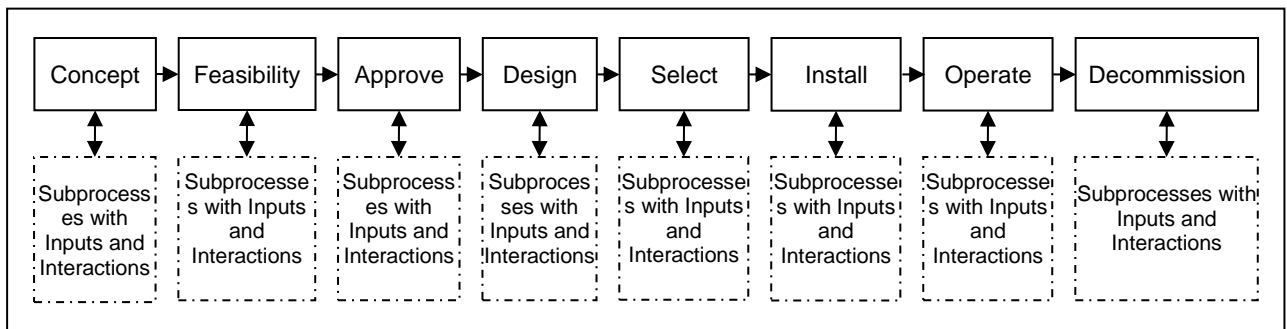


Figure 6.2—A Process Map of an Operating Asset Life Cycle

Equipment Process Maps

The operating equipment process map is used to identify the parts and assemblies that need to be highly reliable and begins the development of strategies to get that outcome. Maximizing equipment reliability requires identifying and controlling component risks—by removing them if possible and unrelentingly reducing them if not. Figure 6.3 is a series of process maps for a centrifugal pump-set representing the equipment’s construction and operation. It helps you identify where failures will stop the equipment from working. With it, you can spot the risks to the

operation by asking at each step in the process, how does failure at this step affect the whole process outcome? Once you find problems, you can identify effective plans and actions to eliminate or reduce the risks.

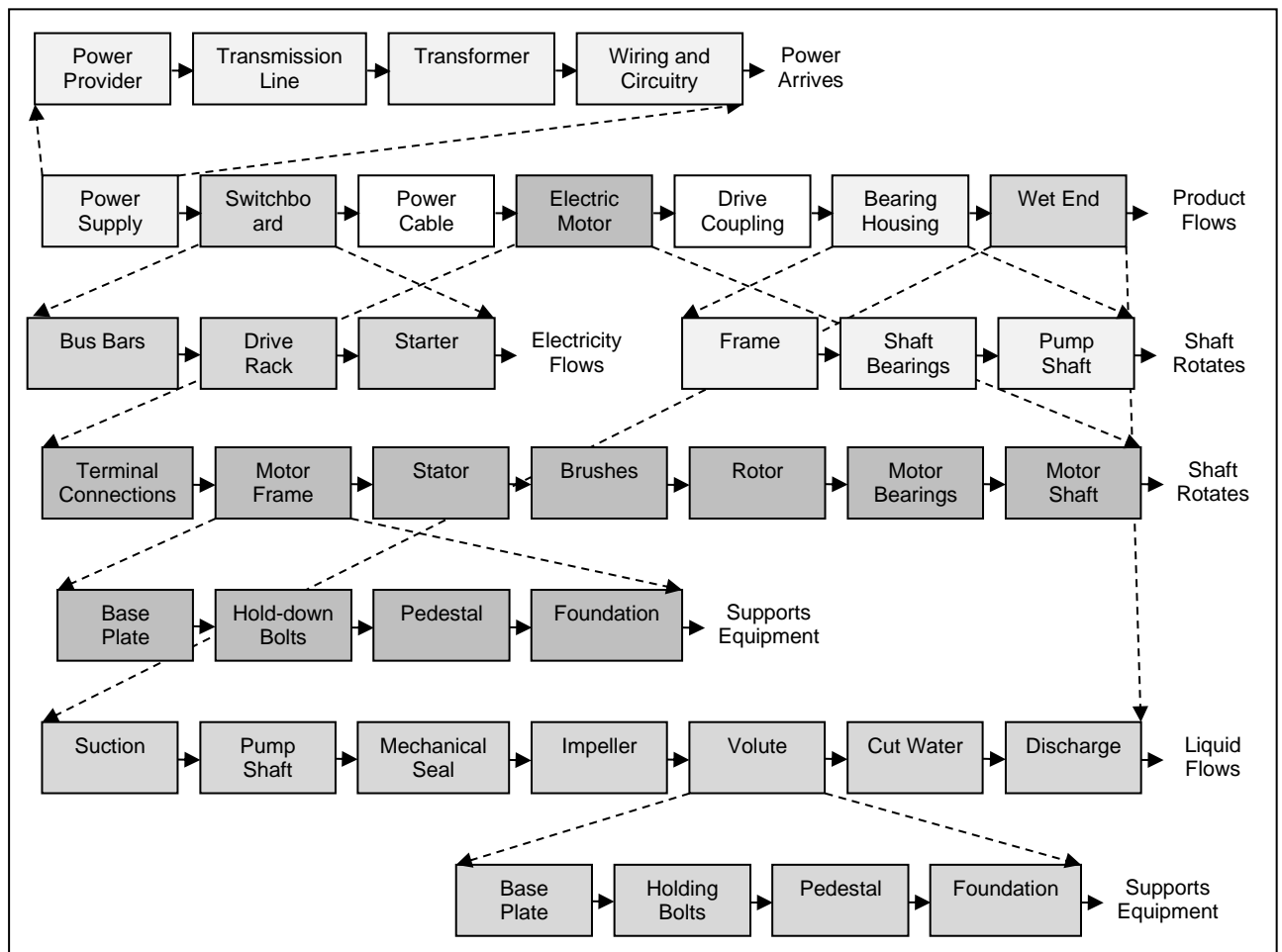


Figure 6.3—A Process Map of a Centrifugal Pump-Set Delivering Product

You will be tempted to think it is sufficient to consult the equipment assembly drawing, exploded parts drawing, and bills of material to identify which components' failure will cause a breakdown. You will not draw a process map because it seems as if all you need to know is in the manufacturer's parts manual sketches and engineering drawings. Those drawings show you how a machine goes together, but they do not show you the logic of the equipment's design. They do

not let you identify the interconnectivity between one part and another. The way a machine and its parts work are best explained in a logical flowchart.

Make the maps detailed enough to use them to identify the operational risks to the equipment being examined. For example, the mechanical seal in the wet-end does not have a process map. When the working parts of a mechanical seal fail, the whole seal becomes unusable, and the pump must be stopped. To identify the consequent impact of seal failure on the pump, we do not need to know every way in which a mechanical seal can be failed. At this stage, we only need to know that when the mechanical seal fails, so does the pump. Similarly, the shaft drive coupling is a single assembly that does not have its own process map because the box on the diagram sufficiently identifies the risks to the parent equipment if that part should fail.

Typically, your process mapping will encompass the major assembly level down to the subassembly level. In some cases, you may want to map an assembly right down to its individual parts and investigate the risks that each part carries. For example, you could expand the “Wiring and Circuitry” box in Figure 6.3 to identify the risks carried by individual components in the power supply system. If it is necessary to understand what might cause the mechanical seal or the coupling or the electrical wiring to fail, the process map for that specific item can then be drawn and analyzed to identify the risks carried by each component.

Expanding an item on a process map lets you see the specific parts causing the risks that it carries. If items are left off a process map, no purposeful risk controls will be installed to protect the equipment. When you are not certain how far to take the mapping, it is better to expand the process map to include more details. For example, the electric motor frame and pump volute were each expanded to include their mounting arrangement because a solid base plate and foundation are critical to the operating life of the pump-set. Had they not been expanded, several common

causes of centrifugal pump failures associated with its base, such as a cracked concrete plinth, a bad support foundation, and vital other needs providing rigidity, would not have been identified.

Using a process map gives you a powerful perspective on risk identification. You can do “what-if” sensitivity analysis and visualize the effects of multiple causes of failure acting together. It lets you ask questions such as, if the motor frame is loose on its base, what else will be affected? Or, if the concrete pedestal cracks, how will it affect the pump-set and motor bearings or the mechanical seal? With a process map, you can better appreciate consequential failures from remote causes that cannot be identified by looking at the engineering drawings.

Here are some guidelines to help develop a useful process map sequence:

- **Follow the path of the force.** From the location where a force is applied, follow the force and loads to the final points of restraint. For example, in Figure 6.4, the torque generated by the electric motor driving the pump is restrained by the hold-down bolts in the pedestal, which is itself embedded in the foundation supporting the whole machine. Ultimately, it is the foundation that restrains all operating forces and loads.
- **Follow the energy flow.** Draw maps starting from the energy source and follow the process to the end. For example, the rotation for the pump-set travels from the motor’s rotating magnetic field through the electric motor shaft, through the connecting coupling, and into the pump shaft.

- **Follow the product flow.** Start mapping at the point at which the material enters and follow the process to the point at which it leaves. For example, the liquid moving through the pump enters at the suction nozzle and leaves at the discharge nozzle.

Most equipment types are used repeatedly in industry. Therefore, once you have the first process map for a type of equipment, you can copy it again and again. Alternating current (AC) electric motors are an example. You can reuse the process map for AC electric motors over a large range of sizes. A 5-kW AC electric motor would have the same process map as an 11-kW electric motor. This saves time analyzing all AC electric motors in an operation. You would not use an AC electric motor process map for a hydraulic motor. The hydraulic motor works in a totally different way to an AC motor. Therefore, a hydraulic motor needs its own process map. But once it is drawn, the process map can be used again for similar hydraulic motors and adjusted for peculiarities.

Collect All Technical Information

Up-to-date process drawings, equipment drawings, general assembly drawings, manufacturer manuals, parts assembly drawings, and bills of material are collected so that they can be reviewed to identify critical equipment in a production process. For critical equipment, critical parts are identified so that appropriate activities can be selected to keep each part at exceptional reliability. Figure 6.4 is an example of an “exploded” general assembly for a small industrial gearbox; it shows how the individual parts are assembled to make the equipment. The same manual will include a parts list that describes each part number shown on the parts assembly drawing.

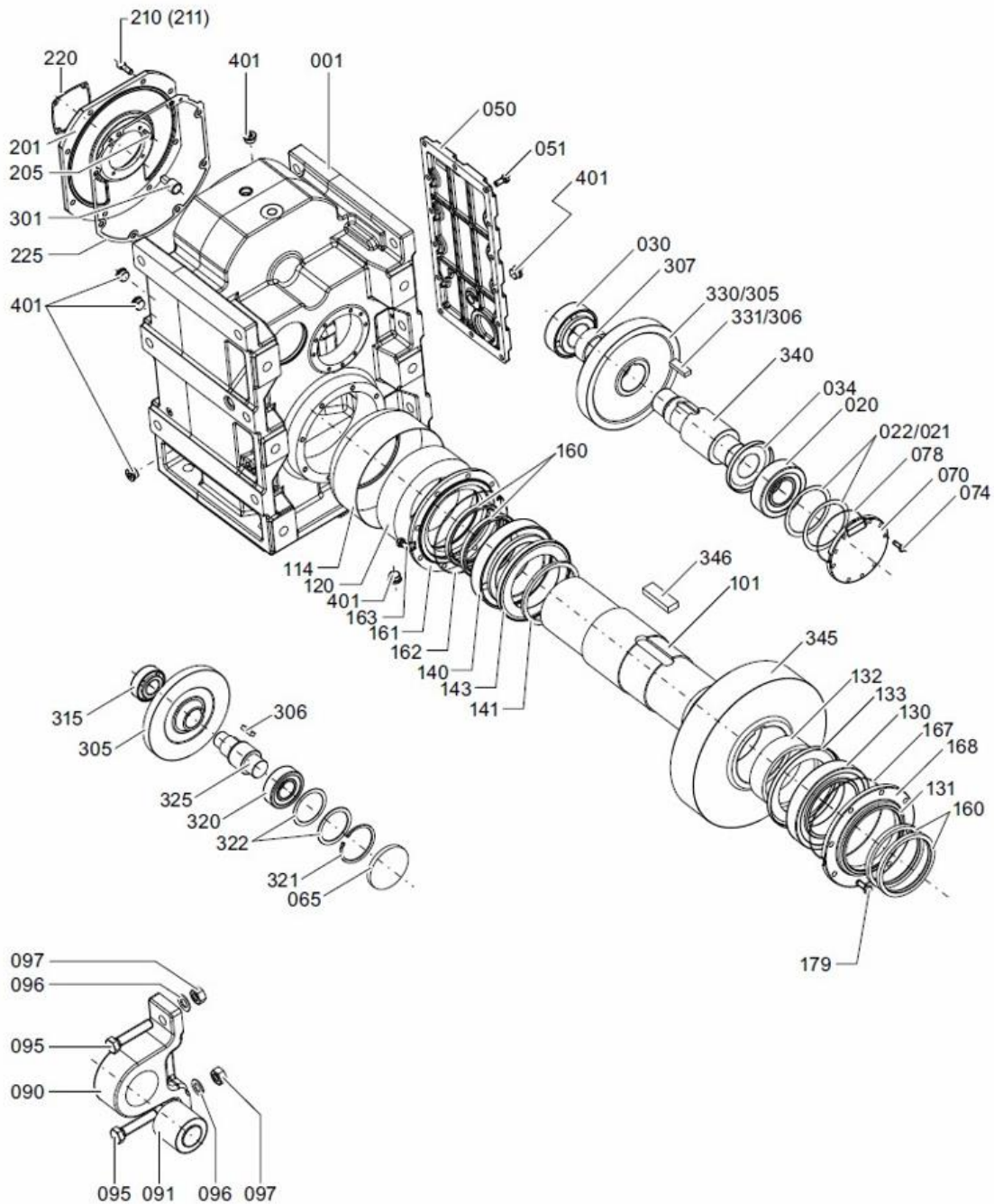


Figure 6.4—Exploded Assembly Drawing of a Gearbox

When a manufacturer uses a specific part numbering sequence, it is adopted in the analysis as well for consistency and easy reference. Throughout the analysis, the same number and description of each part are used in combination with the manufacturer’s part name and model number. When the manufacturer does not have a part numbering classification, you will need to create a part numbering and naming convention. If necessary, “dummy” numbers and codes are

used to create individual numbers for all parts. A suitable part numbering convention takes the following form: Manufacturer code—equipment type—model no.—assembly no.—part no.—part description

Equipment Failure Review

An equipment failure assessment is conducted down to at least the subassembly level. A failure identification table like that in Table 6.1 is developed covering all the assemblies in the equipment. Give each entry a unique number so that it can be identified and referred to in future correspondence and discussion. Write the description for each box on the map in its own row in a spreadsheet so that you can record each failure related to the box as you identify it. The table eventually will encompass the risk analysis and the risk management strategy, plans, and actions you will use to control each risk.

Item No.	Equipment	Assembly	Subassembly	Components	Possible Causes of Failure	Effects of Failure	TDAF Cost of Failure	Comments	
P01	Supply Pump								
1		Power Supply	1. Transmission Line		1. Power provider failure	1. Downtime	\$100,000	\$25,000 per hour, minimum 4 hours if power is turned off	
					2. Lightning strike	1. Downtime	\$200,000	Minimum 8 hours if power is lost due to lightning	
				2. Transformer	1. Poor termination	1. Downtime	\$200,000	Minimum 8 hours if power is lost due to failure	
2		Switchboard	1. Panel		1. Poor termination	1. Downtime	\$200,000	Minimum 8 hours if power is lost due to failure	
					2. Fire	2. Downtime	\$2,000,000	If a person dies, add \$5,000,000 to the TDAF cost	
					2. Liquid ingress	1. Explosion	\$2,000,000	Complete rebuild of switchboard takes two weeks; if a person dies, add \$5,000,000 to the TDAF cost	
			2. Bus Bar		3. Impact	1. Downtime	\$200,000		
					1. Loose clamp bolts	1. Fire in switchboard	\$2,000,000	Complete rebuild of switchboard takes two weeks. If a person dies, add \$5,000,000 to the TDAF cost	
			3. Drive Rack		2. Poor cable crimping	1. Fire in switchboard	\$2,000,000	Complete rebuild of switchboard takes two weeks; if a person dies, add \$5,000,000 to the TDAF cost	
					1. Dust from product	1. Arcing in switchboard	\$200,000		
					2. Poor assembly	1. Arcing in switchboard	\$200,000		
			4. Motor Starter		3. Rack rusted in place	1. Downtime	\$100,000		
	1. Overload	1. Downtime		\$100,000					
			2. Short circuit	1. Major electrical fire	\$2,000,000	Complete rebuild of switchboard takes two weeks; if a person dies, add \$5,000,000 to the TDAF cost			
3		Electric Motor	1. Termination						
			2. Motor		1. Frame				
					2. Base Plate				
					3. Holding Bolts				
					4. Pedestal				
					5. Foundation				
			3. Stator		1. Brushes				
					2. Windings				
			4. Rotor		1. Windings				
					2. Bearings				
	3. Shaft								
4		Drive Coupling							
5		Bearing Housing	1. Frame						
					1. Bearings				
				2. Shaft					

Table 6.1—Risks Identification Table for Pump-Set Parts and Assemblies

Identify and Write Down Failures and Causes

A small team of people knowledgeable about the design, use, and maintenance of the equipment is assembled to work through the maps. They ask what could cause each operating equipment item assembly to fail, including identifying failures from possible combined causes and/or consequential effects. The composition of the team is critical and must contain the necessary design, operation, and maintenance knowledge and expertise covering the equipment being reviewed. Ideally, the operations and maintenance shop floor supervisors are part of the review team so that they understand the purpose of the review and can later support the workplace efforts needed to instigate and implement the risk-control activities that will arise.

The team members brainstorm a list of possible failures for each item in the spreadsheet. They record likely equipment failure causes and their impact on the operation, along with estimated business-wide TDAF costs and useful explanatory comments. Places to look for failure history are in documented records, such as the breakdown and corrective maintenance work noted in the maintenance history, and in the shift-logs kept by the operations and maintenance crews. Once the team has exhausted the list of failure causes for an item, the members review the Physics of Failure Factors guide words to identify other possible risks. Add previously unidentified failures to the analysis spreadsheet as they are found. When the team consensus is that a failure cause cannot happen, indicate that in the spreadsheet's Comments field. But if a team member wants the cause recorded, then do so.

Work Activity Process Maps

Work tasks and activities can also be mapped. If job procedures are available, convert them into process maps. An example of a process map for a clerical task recording important cost

information is shown in Figure 6.5. When job procedures are not available, ask people what they do and record the steps they follow. From the description, develop a work activity process map.

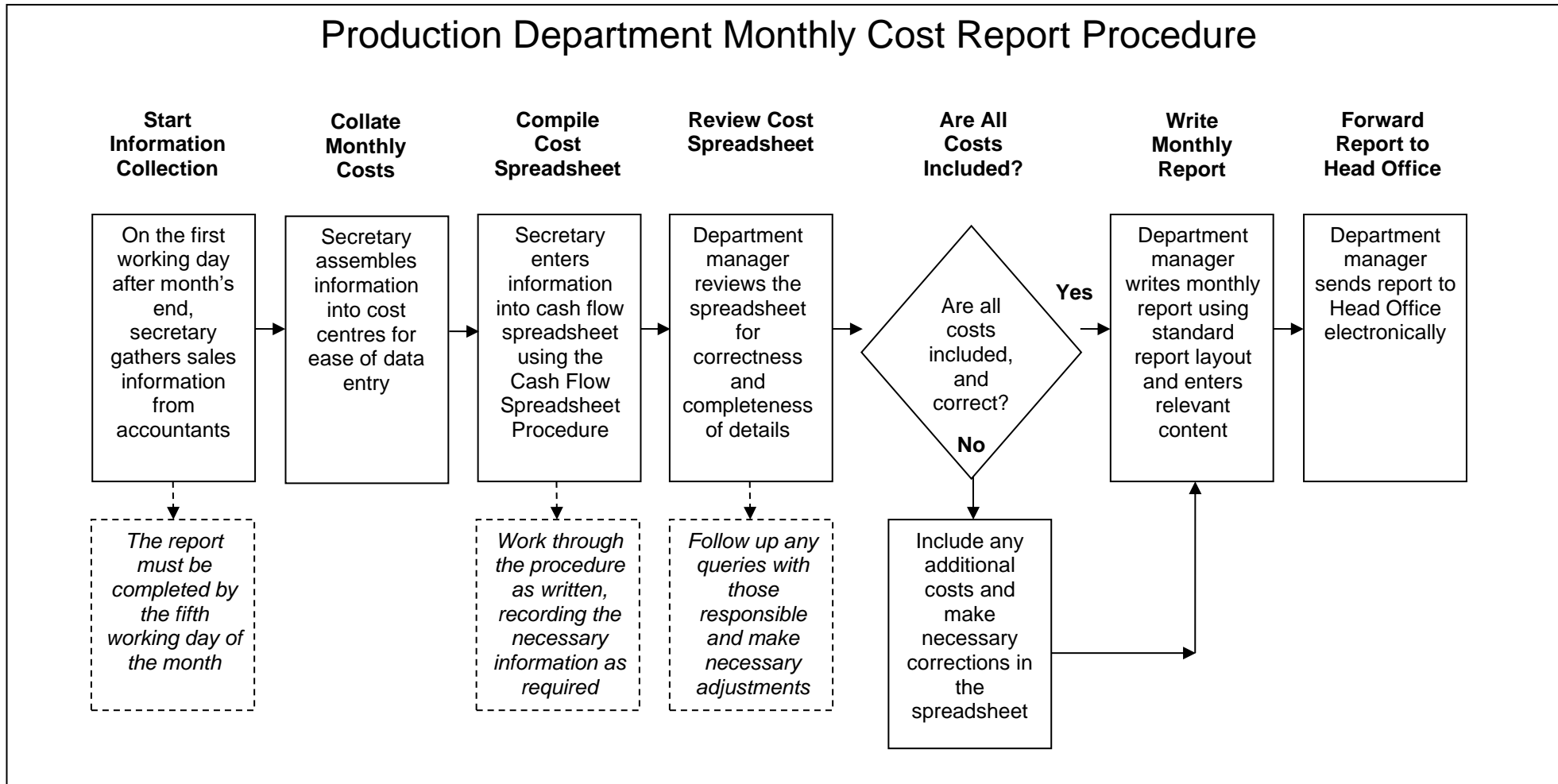


Figure 6.5—A Clerical Job Procedure Converted to a Work Process Map

Work Process Risk Review

Work done by human beings can be done wrong. Mistakes cause risks ranging from no significance to disaster, and adverse risks need to be proactively identified, prevented, and controlled. For human error that cannot be eliminated, you must reduce the consequences of the error. The risk-identification method used for equipment can also be used to identify human error and job quality risks in work processes. The tasks and actions noted on the work process map are recorded in a spreadsheet. Each step is analyzed to find the risks. Table 6.2 lists the work process for Figure 6.5, the Monthly Cost Report, as an example of identifying human error risks in work processes. Risk mitigations typically involve adding parallel test activities or independent double-checks to create error-proofed tasks. Where risk-control actions or parallel proof tests are self-evident, they are added to the table as the risk analysis is done.

Department	Process	Job	Task	Possible Causes of Failure	Effects of Worst Likely Failure	TDAF Costs of Worst Failure	Risk-Control Plans	Actions to Be Taken	Proof That Actions Have Been Completed
Production									
1	Monthly Cost Report								
2		Start information collection	Gather sales information from Accounts	1. Information not available	Report not completed on time	\$500	Warn Accounts of impending report date	Set up an electronic schedule entry to automatically warn Accounts manager one-week prior report due date	Department manager to check schedule entered
				2. Wrong information provided	Bad management decision	\$10,000	Get Accounts to double-check cost information is correct	Accounts to include double check actions into their work procedure	Accounts to send copy of revised procedure to department secretary for review
				3. Incomplete information presented	Bad management decision	\$10,000	Get Accounts to double-check cost information is complete	Accounts to include double check actions into their work procedure	Accounts to send copy of revised procedure to department secretary for review
3		Collate monthly costs	Put costs into cost centres						
4		Compile spreadsheet	Enter cash flow details using data entry procedure						
5		Review cost spreadsheet	Department manager checks spreadsheet						
6			Confirm all costs are recorded						
7		Write Monthly Cost Report	Department manager writes report						
8			Report forwarded to Head Office						

Table 6.2—Risks Identification Table and Risk Management Plan for a Clerical Work Activity Process

Introduction to Total Defect and Failure Costing

Conducting a rigorous risk analysis means compiling the complete business-wide financial costs of a failure incident. The process of collecting, analyzing, and reporting all the costs attributable to a failure is known as total defect and failure costing. It is a formalized accounting process that shows the vast amounts of money wasted throughout an organization from equipment failures. To assist in compiling the TDAF cost list, it is useful to use the company's chart of accounts, as it contains all of the accounting cost codes for allocating costs and charging payments in the organization. New cost centers usually need to be developed to capture all TDAF costs. The methodology brings together the financial, production, engineering, and maintenance groups. It provides a means for these normally separate groups to work together to solve problems of serious financial waste.

Calculating TDAF Costs Using Activity-Based Costing

The TDAF cost methodology is activity-based costing (ABC) applied to a single failure incident. The goal is to identify the total costs of failure and to either accept such failures in the future or put in place mechanisms and solutions to prevent them. Activity-based costing is an accounting method that identifies the total costs of the deeds undertaken to perform a function or produce a product. Activity-based costing applied to TDAF costing allows an organization to determine the actual costs of all resources and services wasted by a failure. It is a powerful technique for measuring failure costs because it itemizes every expense and identifies its makeup. With TDAF costing, you trace failure cost surges throughout your organization and quantify all lost profit.

Steps for Performing TDAF Costing

Once a failure event is specified, there are five phases of TDAF cost analysis.

1. Define the project and its scope
2. Identify activities attributable to the failure event
3. Gather the surge costs throughout the business
4. Trace and allocate costs to activities
5. Report the analysis findings

A person with access to costing data from your accounting system and maintenance management system who is comfortable developing financial spreadsheets can perform these steps. In the case of a sufficiently large incident, a small team of people may be committed to the project. The person or core team responsible for the analysis develops TDAF cost tables, selects key people to interview, collects activity information, and identifies all costs related to the failure. Additional support can come from other knowledgeable people in the organization or from consultants. The investigation and costing process can take anywhere from a few days to a few weeks. The duration depends on the scale of the incident, the level of detail required, the complexity of an organization's processes, and the availability of resources. The investigation ought to be managed as a project using established and sound project management tools and techniques.

Define the Scope of the Investigation

Specify the scope of the investigation and settle project management issues such as those listed below. The departmental groups involved in the failure incident and those conducting the analysis should be included in setting the scope of the investigation.

1. The period (start, duration, and end) over which the failure incident and its effects are to be investigated
2. How the investigation is resourced
3. How long to spend on the analysis before a final report is provided
4. The business, production, and maintenance processes to be investigated
5. The accounting cost centers to be analyzed
6. Costing table contents
7. Who is to be interviewed to get a complete picture of the event and its costs?

Identify Failure Incident Activities

Usually, it is simplest to start the investigation by finding out everything that was done to recover from the failure event. Every consequential action and its cost are required. Information can be found in maintenance work orders, purchase orders, operator and maintainer logbooks, process control computers, and interviews with those involved in the incident and recovery. The sample TDAF costing worksheet accompanying this book has a comprehensive list of surge costs to be traced. If you have other activities specific to the incident, include them in the analysis.

Gather All Costs of Failure

Trace all surge costs to the expenditure records whenever possible. They are undisputable proof of the real costs. These records include salaries and wages, payments for parts and materials, replacement machinery, hired equipment, subcontract services, and so on. It is best to get documentation of all costs so that any future disputes and queries can be readily resolved. When documents for the true costs incurred are not available, use cost assignment formulas based on the historical costs of similar activities.

Trace Costs to Activities

In this step, connect surge costs to the activities they came from. Develop a TDAF costing worksheet that matches every surge cost to its failure recovery activity. Allocate all expenditures caused by the incident—wages and salaries, maintenance purchases, outside services, and so on. Allocate all losses resulting from the failure, including production waste, energy losses, and opportunity costs.

Prepare the Final Report

Finally, produce a succinct final report explaining the effect of the failure on the organization's resources and productivity and the resulting TDAF costs incurred by the operation.

How to Develop TDAF Cost Tables

Follow these steps to create a TDAF cost table:

1. Identify each organizational department and work group involved in the incident.
2. Identify every person in each department or work group involved in or affected by the incident. Determine what each person did during the incident and the total normal time and penalty time spent or lost on failure-related activities.
3. Identify each person's gross hourly normal time and penalty time cost. The gross hourly cost typically includes an overhead component of all fixed operating costs, administrative, engineering, and management costs. This overhead is on top of base salary or wage packages. For shop floor employees, the gross cost is often more than twice the hourly pay rate. If the pay rates do not include an overhead component, you will need to calculate it

and add it to the rate.

4. Identify every organizational process disrupted by the incident. This includes manufacturing processes and all business and administrative processes such as accounts receivable, secretaries, inward goods receipt, forklift drivers, and so on. Identify every labor cost.
5. Find each purchase order attributable to the incident and see what was bought. Interview those people involved in the incident to identify all materials and resources purchased or used.
6. Identify every material scrap and waste resulting from the incident. Even if the material is salvageable, it is an extra cost incurred because of the incident. Calculate the cost of the material up to that point in the process (e.g., cost per kilogram, cost per tonne, cost per part, cost per meter).
7. Identify all rework costs for salvageable materials per unit measure of the material (e.g., cost per kilogram, cost per tonne, cost per part, cost per meter).
8. Include the expected revenue from sales of all products normally made but stopped by the failure. Production not intended for sale is not included as a failure cost, as there is no opportunity cost lost. If production not made because of the failure causes the loss of a current customer or the loss of a definite new customer, count the foreseeable revenue lost as a cost.
9. For repaired and replaced plant and equipment, identify the wasted proportion of parts' lives for any part replaced because of the failure. The curtailed lives had value. If they worked to the end of their natural "wear-and-tear" life, no value was lost. If they failed before their natural end, then estimate the value of material, labor, and subcontracted services wasted.
10. Using a spreadsheet, create the TDAF cost tables.

Examples of the spreadsheet columns and listings used to capture failure costs in a manufacturing organization are given in Tables 6.3 to 6.7.

Labor Costs

- Start a worksheet to capture labor costs.
- In the first column, list each department involved.
- In the second column, list each department process affected.
- In the next column, list the position title of each departmental employee affected in each process. The same employee may appear more than once.
- In the fourth column, indicate all work each employee did because of the incident. If more than one task was done, record them all in individual rows. If other duties were done as unnecessary work but occupied time, record those as well.
- Beside that column, list the gross normal shift hourly rate.
- In the next column, list the total normal shift hours worked, or portions of an hour (e.g., 0.25, 0.5), for each person involved in or affected by the incident.
- In the column beside list their penalty shift hourly rates.
- In the next column, list the total overtime shift hours worked at penalty rates, or portions of an hour, for each person involved in or affected by the incident.
- In the final column, calculate the total cost of all labor.

Labour Costs Incurred by the Organization Because of a Failure Incident								
Department	Process Affected	Employment Position Affected	Work Done	Normal Hourly Gross Rate	Total Normal Hours	Penalty Hourly Gross Rate	Total Penalty Hours	Total Labour Cost
Production	Process Line 1	Equipment Operator 1	Clean-up					
			Set up again					
		Equipment Operator 2	clean-up					
			Set up again					

		Production Supervisor 1	Inspect failure					
		Production Manager 1	Inspect failure					
Maintenance	Mechanical	Trades Fitter 1	Strip machines for clean up					
		Trades Assistant 1	Assist fitter					
		Maintenance Supervisor 1	Inspect repair					
	Electrical	Electrician 1	Remove burned control panels					
			Install new control panels					
		Electrical Supervisor 1	Inspect repair					
	Stores	Storeman 1	Receive/store new panels					
		Maintenance Engineer 1	Inspect failure					
			Inspect repair					
		Maintenance Manager 1	Inspect repair					
Administration		Secretary 1	Compile failure report					
		Senior Executive Manager 1	Attend site meeting					
Finance		Accounts Receivable 1	Process purchase orders/invoices					
TOTAL COST								

Table 6.3—Labor Costs Incurred by the Organization Because of a Failure

Purchased Materials and Services

- Start a second worksheet to capture purchases of materials, goods, hired equipment, subcontractors, service specialist, and so on.
- In the first column, list each department involved.
- In the second column, list each department process affected.
- In the third column list all the plant, equipment, and machinery affected by the incident. The costing goes as far as recognizing the use of paper and ink for reports.
- In the fourth column, list the materials and purchased services used.
- In the next column, list all invoiced costs, or portions of invoiced costs, for every plant, equipment, and machinery affected by the incident.
- In the final column, calculate the total cost of all purchases.

Purchased Materials/Services Costs Incurred Because of a Failure					
Department	Process Affected	Plant, Equipment, and Machinery Affected	Parts, Materials, Services Purchased	Total Invoiced Purchases	Total Cost
Production	Process Line 1	Manufacturing Equipment 1			
		Manufacturing Equipment 2	Electrical control cabinet		
			Electrical motor draw		
			Electrical cable		
			Process computer programmer		
		Manufacturing Equipment 3			
		Forklift 1			
		Production Building 1	Power supply cabinet		
Maintenance	Mechanical		Mechanical consumables		
			Nuts and bolts		
	Electrical		Electrical consumables		
	Stores	Facsimile	Paper		
Administration		Printer	Report materials—paper, ink, binder		
		Facsimile	Paper		
Finance		Printer	Purchase orders		
TOTAL COST					

Table 6.4—Purchased Materials/Services Costs Incurred Because of a Failure

Material and Product Waste

- Start a third worksheet to capture material and product waste costs.
- In the first column, list each department involved.
- In the second column, list each department process affected.
- In the third column, list all the plant, equipment, and machinery affected.
- In the fourth column, list each item of material waste identified for the equipment.
- In the fifth column, list the unit cost of each waste at its value up to that point in production (e.g., cost per kilogram, cost per tonne, cost per part, cost per meter). Add any additional unit cost for rework of salvable items to the initial value.
- In the next column, indicate how much of each waste unit was present.
- In the final column, calculate the total of all material waste.

Material and Product Waste Attributable to a Failure						
Department	Process Affected	Plant, Equipment, and Machinery Affected	Materials, Products Wasted or Reworked	Unit Cost of Waste/Rework	Total Wasted/Reworked Units	Total Waste Cost
Production	Process Line 1	Manufacturing Equipment 1	Raw materials for the line	Cost per kilogram		
			Product in Equipment 1	Cost per unit		
		Manufacturing Equipment 2	Product in Equipment 2	Cost per unit		
		Manufacturing Equipment 3	Product in Equipment 3	Cost per unit		
		Forklift 1				
		Production Building 1				
Maintenance	Mechanical					
	Electrical					
	Stores	Facsimile				
Administration		Printer				
		Facsimile				
Finance		Printer				
TOTAL COST						

Table 6.5—Material and Product Waste Attributable to a Failure

Lost Opportunity Costs

- Start a fourth worksheet to capture lost opportunity costs.
- In the first column, list each department involved.
- In the second column, list each department process affected.
- In the third column, for each process, record the opportunities lost because of the incident, such as the following:
 - Lost sales that would have happened
 - Double handling, where the second handling prevented normal work
 - Production volume lost because of downtime, rework, and time lost to cleaning of equipment and production lines
 - Medical expenses for accident victims
- In the next column, indicate the unit cost of each lost opportunity (e.g., cost per kilogram, cost per tonne, cost per part, cost per meter).
- In the next column, indicate how much of each lost unit was present.

- In the final column, calculate the total of all lost opportunities.

Lost Opportunity Costs Attributable to a Failure					
Department	Process Affected	Opportunity Lost	Unit Cost of Lost Opportunity	Units Lost	Total Lost Opportunity Cost
Production	Process Line 1	Profit on sales from 24 hours of lost production			
		Curtailed lives of repaired and replaced equipment			
Maintenance	Mechanical				
	Electrical				
	Stores				
Administration					
Finance		Money for Process Line 1 cost reduction spent on repair			
Sales	New Customer	Future sales revenue			
TOTAL COST					

Table 6.6—Lost Opportunity Costs Attributable to a Failure

Summary of Costs

In a separate worksheet, create a summary spreadsheet showing the separate cumulative costs for each category and the grand total cost.

Summary of Costs Incurred Because of a Failure	
Cost Category	Final Cost
Labour Cost	
Purchased Materials/Services Cost	
Material and Product Waste Cost	
Lost Opportunity Cost	
TOTAL TDAF COST	

Table 6.7—Summary of Costs Incurred Because of a Failure

Risk Rating with TDAF Costs

Once the TDAF costs for your equipment are estimated, Process 1 is completed. The TDAF costs provide honest identification of the total value of losses and waste that a company suffers from an equipment failure. Putting a believable business value to failure is important. Doing risk mitigations without knowing the benefit of addressing the risk makes managers uncomfortable. They need a credible value for their financial investment modeling and business case justification. Once all the money lost by a failure event is known, company management has the correct information to make sound decisions regarding appropriate actions to take. TDAF costing provides a believable and traceable monetary value for managers to use because the costs are drawn from the company's own accounting and business systems. None of the costs are wild guesses; rather, they are estimates calculated from real details. Managers can be more confident in making good decisions when they have a true value of the consequences they must address.

The consequential TDAF cost value of risk found in Process 1 is used in Process 2. With the cost consequences of a failure known accurately, the only remaining uncertainty in a risk analysis is the frequency of a failure event. This represents the likelihood of it occurring in the operation being analyzed. In IONICS Process 2, you will identify the event likelihood and determine the current business risk from your equipment failures.