Root Cause Analysis 101 Guidebook

What You'll Learn:

> 5 of the most common root cause analysis methods
> The fundamentals of using each to effectively identify root causes
> When to use one method over the others to solve problems

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Introduction and Overview

Next to defining a problem accurately, root cause analysis is one of the most important elements of problem-solving in quality management. That's because if you're not aiming at the right target, you'll never be able to eliminate the real problem that's hurting quality.

Imagine a scenario where you're seeing increasing downtime on a machine that's critical to meeting your production quotas. Investigation reveals that operators have to keep adjusting the machine due to a misalignment issue. Digging even deeper, you determine the alignment issue is itself the result of worn seals that are due for replacement.

Three months after replacing the seals, however, you discover the real root cause wasn't just a maintenance issue on the one machine. As downtime steadily creeps up, you discover that your preventive maintenance program doesn't capture seal replacement across several machines.

The result: what was initially a problem with a single machine is cutting into productivity in multiple areas. What's more, it's happening just as orders are surging and you've won your biggest contract to date.

In fact, according to Aberdeen research, machine downtime costs companies an average of $260,000 per hour[1]. It's a hefty price to pay, to say nothing of the potential for quality escapes when you resume production behind schedule and in a rush.

Had your root cause analysis process gone one step further, you might have identified the true cause of the downtime earlier, rather than just fixing a symptom of the problem once it arose.

This scenario highlights the importance of getting root cause analysis right, examining problems deeply rather than just assuming you know the source of the problem. Many root cause analysis methods are available to help manufacturing professionals do just that—the key is choosing the right ones for your situation.

So which type of root cause analysis tool is the best one to use? Manufacturers have a range of methods at their fingertips, each of which is appropriate for different situations.

In this guide, we discuss five common root cause analysis tools, including:

- Pareto charts
- The 5 Whys method
- Fishbone diagrams
- Scatter plots
- Failure mode and effects analysis (FMEA)

[1] Aberdeen, The Rising Cost of Downtime

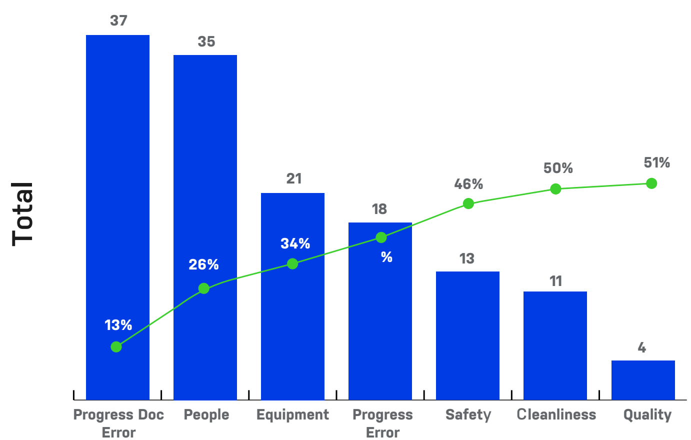
Pareto Charts

A Pareto chart is a histogram or bar chart combined with a line graph that groups the frequency or cost of different problems to show their relative significance. The bars show frequency in descending order, while the line shows cumulative percentage or total as you move from left to right.

The Pareto chart example below is a report from the EASE plant floor audit software that groups together the top seven categories of failed audit questions for a given manufacturing facility.

Pareto charts are one of the seven basic tools of quality described by quality pioneer Joseph Juran. Pareto charts are based on Pareto's law, also called the 80/20 rule, which says that 20% of inputs drive 80% of results.

Failures by Category



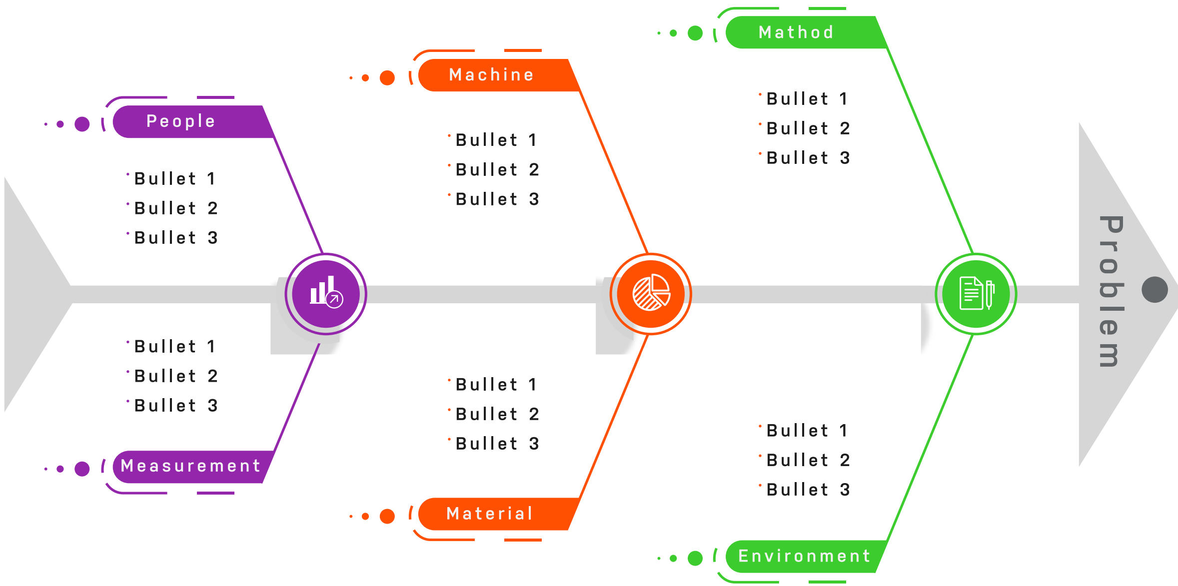
The 5 Whys Method

The 5 Whys is a method that uses a series of questions to drill down into successive layers of a problem. The basic idea is that each time you ask why, the answer becomes the basis of the next why. It's a simple tool useful for problems where you don't need advanced statistics, so you don't necessarily want to use it for complex problems.

Of course, it may take asking why more than five times to solve the problem—the point is to peel away surface-level issues to get to the root cause.

Fishbone Diagrams

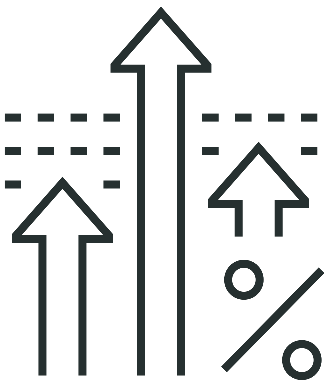
A fishbone diagram (see template below) sorts possible causes into various categories that branch off from the original problem. Also called a cause-and-effect or Ishakawa diagram, a fishbone diagram may have multiple sub-causes branching off of each identified category.



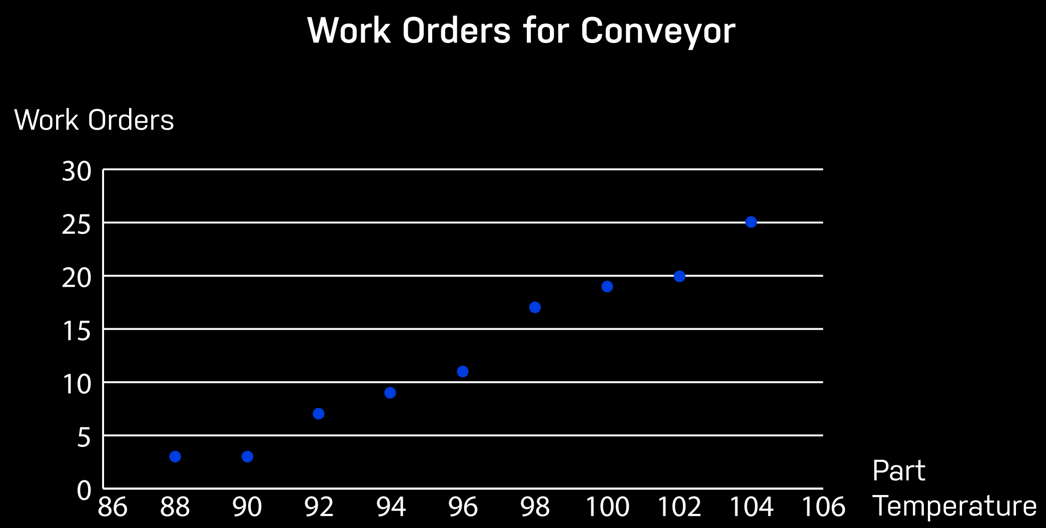
Scatter Plots

A scatter plot or scatter diagram uses pairs of data points to help uncover relationships between variables. A scatter plot is a quantitative method for determining whether two variables are correlated, such as testing potential causes identified in your fishbone diagram.

Making a scatter diagram is as simple as plotting your independent variable (or suspected cause) on the x-axis, and your dependent variable (the effect) on the y-axis. If the pattern shows a clear line or curve, you know the variables are correlated and you can proceed to regression or correlation analysis.



Part Temperature	Work Orders for Conveyor
88	3
90	3
104	25
92	7
94	9
96	11
102	20
100	19
98	17



Failure Mode and Effects Analysis (FMEA)

Failure mode and effects analysis (FMEA) is a method used during product or process design to explore potential defects or failures. An FMEA chart outlines:

> Potential failures, consequences and causes

> Current controls to prevent each type of failure

> Severity (S), occurrence (O) and detection (D) ratings that allow you to calculate a risk priority number (RPN) for determining further action

Failure Mode and Effects Analysis Template

Process	Failure	Effect	S	Potential Causes	O	Controls	D	RPN

When applied to process analysis, this method is called process failure mode and effects analysis (PFMEA). Many manufacturers use PFMEA findings to inform questions for process audits, using this problem-solving tool to reduce risk at the source. No matter which tool you use, root cause analysis is just the beginning of the problem-solving process. Once you know the cause, the next step is implementing a solution and conducting regular checks to ensure you're holding the gain and achieving sustainable continuous improvement.

In the following chapters, we provide a more in-depth look at each of these methods. You'll find details on how to use them and manufacturing examples and pitfalls to avoid.

CHAPTER 1

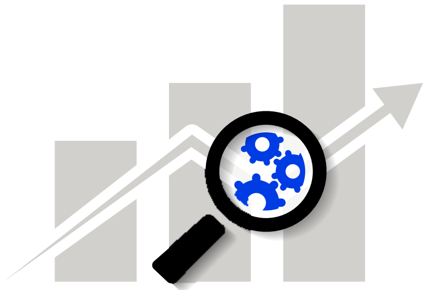
Pareto Charts

The Pareto Principle is a universal pattern that exists everywhere in the world, including in manufacturing. It's a simple yet powerful rule that can help you identify waste in your processes and help you conduct more effective root cause analysis.

In the 19th century, Italian economist Vilfredo Pareto observed that 80% of the wealth in Italy was held by 20% of the population. While ahead of its time, this concept was later found to apply to nearly every relationship imaginable:

- 80% of the work in a department is completed by 20% of its people
- 80% of the errors in a production line come from 20% of its machines
- 80% of a firm's problems come from 20% of the causes
- 80% of bad parts come from 20% of suppliers

In the manufacturing environment, creating a Pareto chart is a great way to visualize this concept. The chart will not only show you where your problems are, but point you in the right direction when conducting root cause analysis.



Collect Your Data

As with many quality processes, it all starts with data collection. First, you have to choose what you're going to count and for how long. For example, let's say you have an assembly line that stops a lot and you want to figure out why. Any number of reasons could be causing the problem, so you'll need to make a list of the common causes and count when they happen.

In this scenario, the assembly line stops because of one of the following reasons:

- Missing parts
- Missing tools
- Wrong parts
- Blocked line
- Maintenance issues
- Other

The "other" category is for issues you haven't thought of yet. The next step is to sit on the line each day for a set period of time—let's say five days straight—and mark down when the line stops moving and why.

If it's a missing part, record an occurrence for that category. If the line can't move because the area ahead of it isn't moving, record an occurrence in the blocked line category. Once observation is complete, you can put the data into a graph format.

Create Your Pareto Chart

Now that you have your numbers, let's arrange them in a way that makes sense of the data. You can do this in Excel, or if you're using automated audit and inspections platform software like EASE, it will create the graph for you.

Step 1: Tally Your Data

This is the easy part. Take your notes from your observations and tally up all of the occurrences for each category. In this example, your table might look something like this:

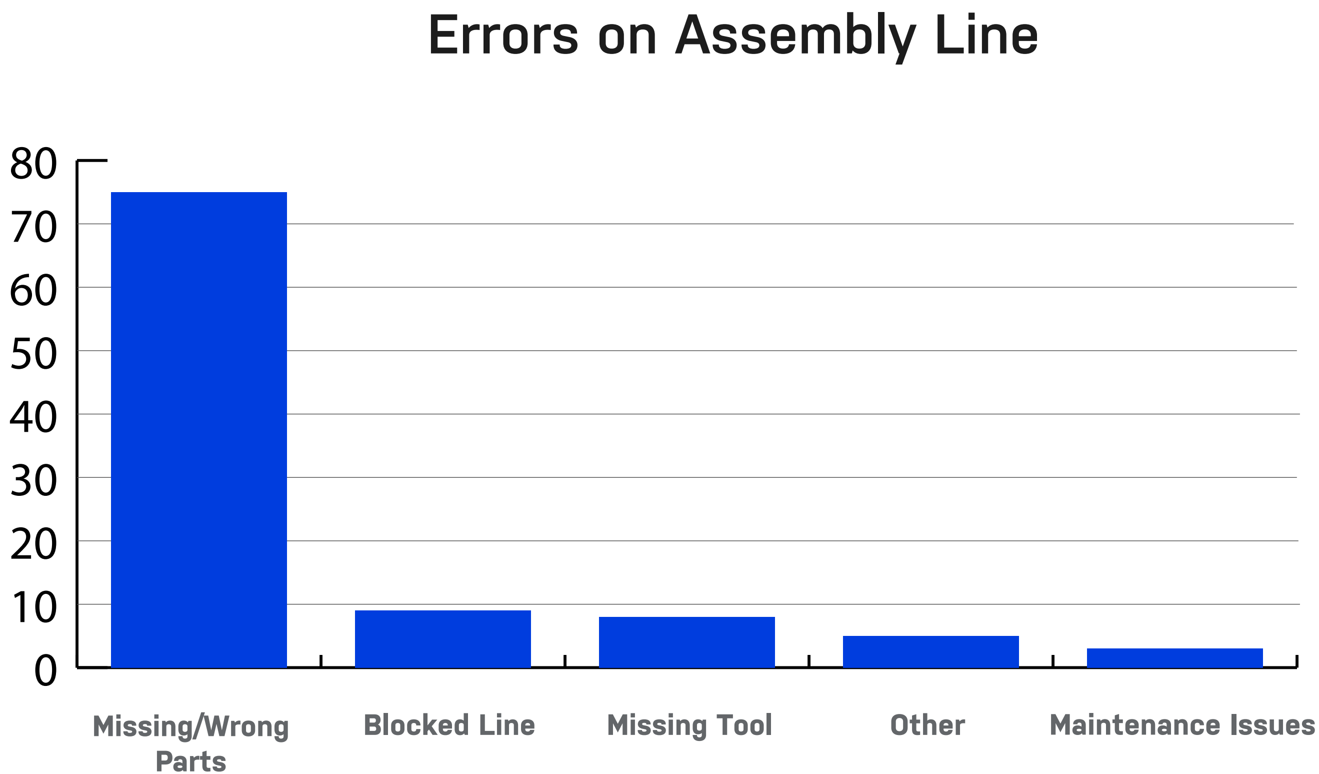
Error	Occurence
Missing/Wrong Parts	75
Blocked Line	8
Missing Tool	6
Other	4
Maintenance Issues	2

Step 2: Re-Order Your Data

The next step is to reorder your data with the highest number of occurrences first, and even here you'll be able to start picking out a pattern.

Step 3: Create Your Bar Graph

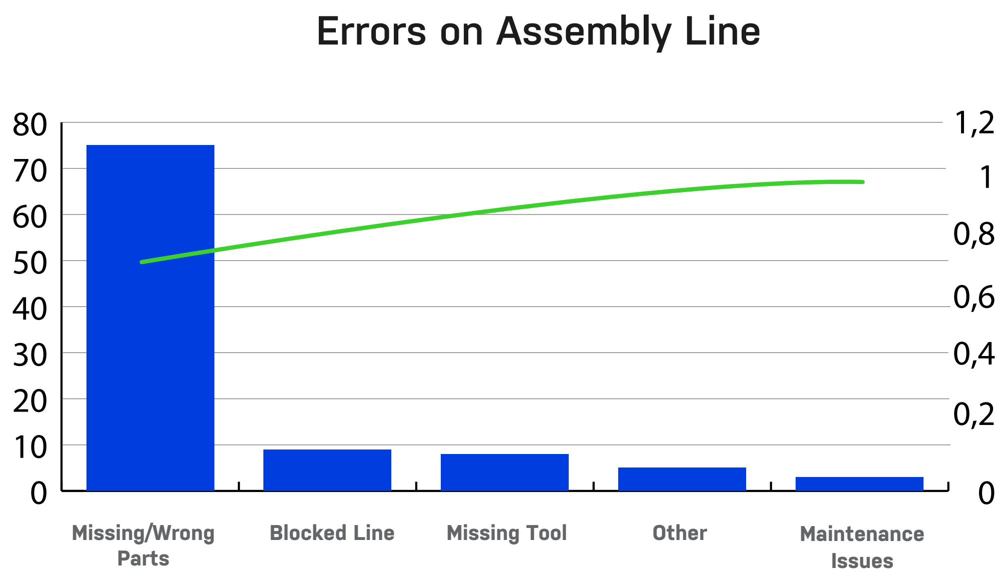
Now that your information is in order, create a bar graph with your reordered data.



Step 4: Add Your Cumulative Line

This last step is the trickiest part, but it is the heart of the Pareto chart. Create a cumulative count of all errors and graph it as a new line. Adding this line will give you a visual of where the bulk of your problems are. You'll need to change the cumulative data to a line and plot it on the secondary y-axis so that it shows the correct proportion of errors. The purpose of this cumulative line is to show how aggressively each new item adds to the overall number of errors. You may find in your root cause analysis that multiple errors add up to 80% of problems.

This is where software like EASE helps not only capture the data, but also create the Pareto chart automatically from plant floor audit or layered process audit data.



How to Use Your Pareto Chart

From here, you can see plainly where you should focus your efforts. In this example, the Missing/Wrong Parts category is the biggest contributor to the line stoppage issue. If you repeated the observations and just recorded parts issues in more detail, you would see another Pareto pattern emerge.

By focusing on the aspects of a process that are creating the most waste or defects, you can set yourself up to solve the problems with the most impact first. It's important to note that not all problems are equally important to solve. Sometimes it's more beneficial to hit the complicated problem that happens often instead of the simple problem that only happens once a year.

It all comes down to assessing which issues carry the biggest risk to customers, your organization and overall safety and quality. Pareto charts can be tricky to master, but once you get the technique down, you'll find them a powerful tool for root cause analysis and improving quality.

What Are Layered Process Audits?

Layered process audits (LPAs) are a system of quick daily checks of process inputs conducted by people at multiple levels of the organization. By examining upstream inputs, LPAs find process variations that cause defects so you can:

- Find and fix hidden problems faster
- Reduce customer complaints and costs
- Promote one-on-one discussions and employee engagement
- Make management a visible presence on the plant floor or workplace
- Foster a culture of quality

Layered checks are what make the difference when compared with other plant floor audits and inspections. More people checking high-risk processes more frequently adds up to more eyes on your process and more opportunities to catch problems.

Learn More

Get LPA strategies, tips and best practices with our free Ultimate Guide to Layered Process Audits

CHAPTER 2

The 5 Whys Method

How many times can you remember thinking you understood the cause of a problem, only to have it come back even after you "fixed" it?

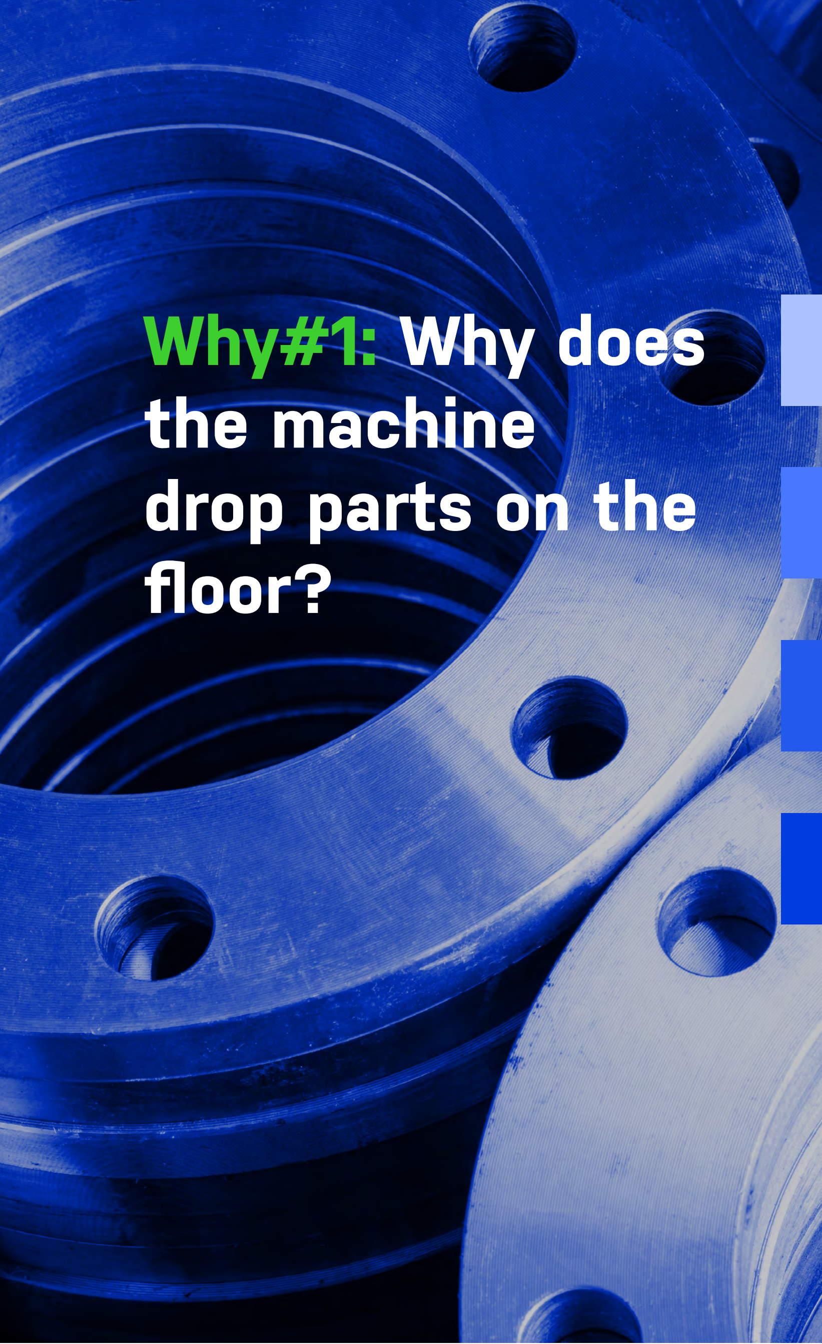
Using the 5 Whys method can help avoid this type of situation by ensuring you dig deeper into problems—which is essential for developing solutions that reduce waste and cost.

What is the 5 Whys Method?

Developed as part of the Toyota Production System and prevalent in Lean methodologies today, the 5 Whys method involves asking 'why' repeatedly to uncover successive layers of a problem.

First, you look at a problem and ask why it happened. Once you answer the first question, you ask why that happened. Repeat this process five times in total and you will have typically found your true root cause.

The 5 Whys is one of the simplest root cause analysis tools available, and is useful for straightforward problems that don't require advanced statistics. Let's look at a detailed example of how to apply this method and what to do with findings to keep the problem from coming back.



Why#1: Why does the machine drop parts on the floor?

The first answer you need is why the part doesn't reach the conveyor. It could be any number of situations:

1. The gripper on the arm may open too soon
2. The arm may not reach the proper position over the conveyor
3. The conveyor or arm's base might be in the wrong position
4. The part may be slipping out of the gripper

In this example, you find that the machine arm won't rotate fully to reach the conveyor.

Why #2: Why won't the machine arm reach the conveyor?

Just like in the first why, you have to look into why the arm won't reach the conveyor, which could also be caused by any number of problems:

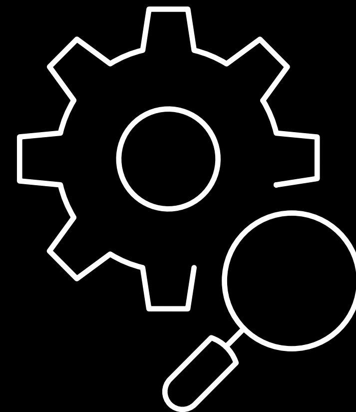
1. The gears could be broken
2. The arm could be twisted, crooked or bent
3. The base of the machine arm could be rotated out of its correct position

A critical step at this stage is to not assume, but dig in and answer the question specifically. In this example, you find that the scraper seal at the base of the arm's rotational base is stopping the arm from rotating fully.

Why #3: Why is the scraper seal out of position?

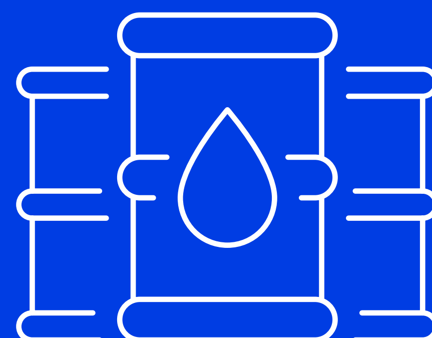
In the base of the machine arm, a scraper seal has come loose and become bound up, preventing the arm from rotating fully. As with previous steps, the reason why could be any one of a long list of possibilities. In this example, you find the seal is too dry and got pushed out of position by the arm.

Now that you know the seal isn't properly lubricated, you may think you're done. However, it would be a mistake to simply service the machine and move on. You need to keep asking why to get to a permanent solution that prevents recurrence.



Why #4: Why wasn't the scraper seal lubricated?

You ask the line supervisor if the operator is supposed to lubricate the machine at any point. The supervisor confirms that the operator is supposed to lubricate the machine every 10,000 cycles and you see this reflected in his standard work.



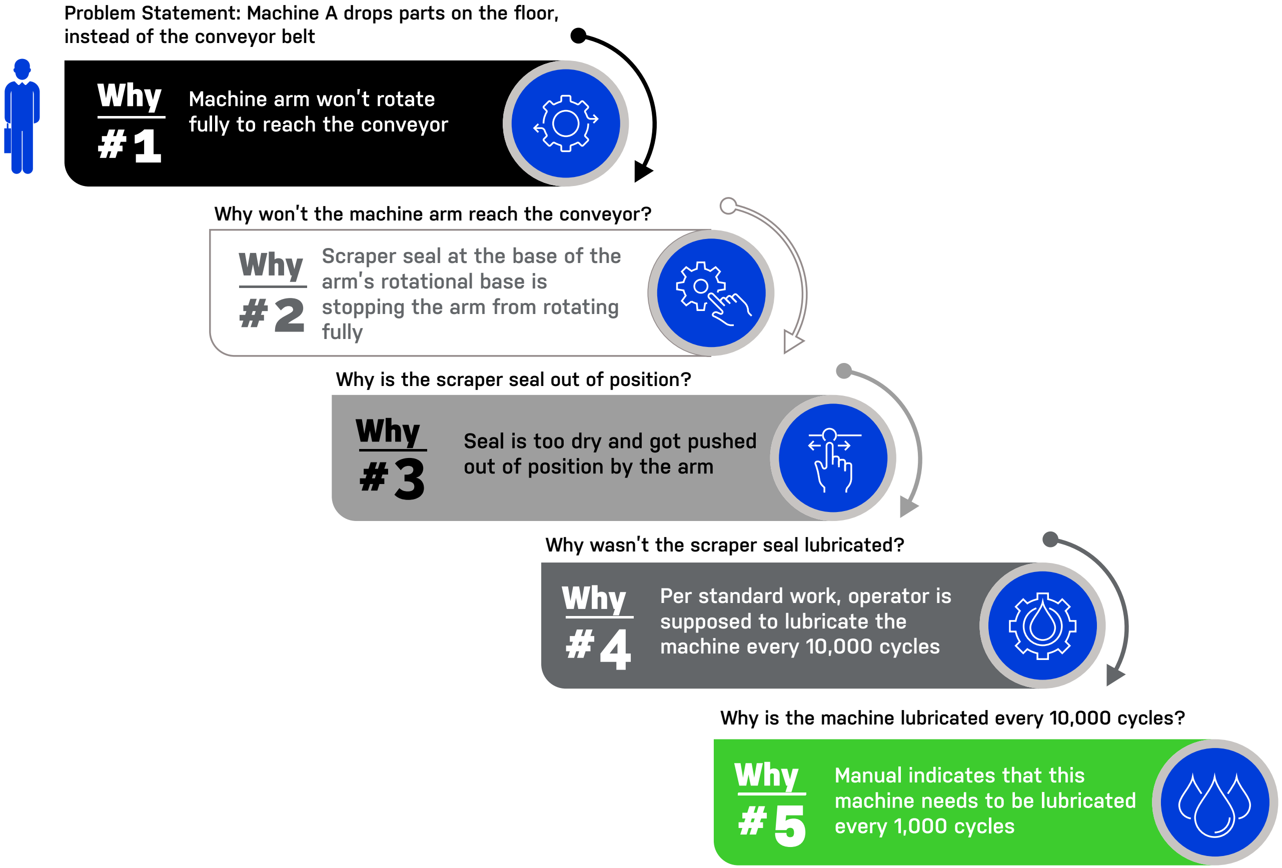
Why #5: Why is the machine lubricated every 10,000 cycles?

You ask the process engineers who wrote the standard work about the lubrication step. Where did it come from? They tell you that it's in the machine's manual.

Inside the manual you learn that this machine needs to be lubricated every 1,000 cycles. Now you have identified the root cause of the problem: the machine has not been serviced frequently enough. In essence, a simple typo has led to an increase in scrap rate.

5 Whys Example

Let's say scrap costs are significantly higher on one of your lines compared to the others. The first step is to write a problem statement.



CHAPTER 3

Chapter 3: Fishbone (Ishikawa) Diagrams

When tasked with solving a problem, brainstorming potential causes is a good place to start. However, without a way to organize the information visually, it can be hard to see how different facets of the problem interact.

One visual method of root cause analysis that helps do just that is the fishbone diagram.

Using this method allows you to visualize and organize potential causes of a problem into a useable framework for solving it. Here we look at the basics of how a fishbone diagram works, as well as some examples of how to apply it in your facility.

What is a Fishbone Diagram?

A fishbone diagram, also called an Ishikawa diagram, is a visual method for root cause analysis that organizes cause-and-effect relationships into categories.

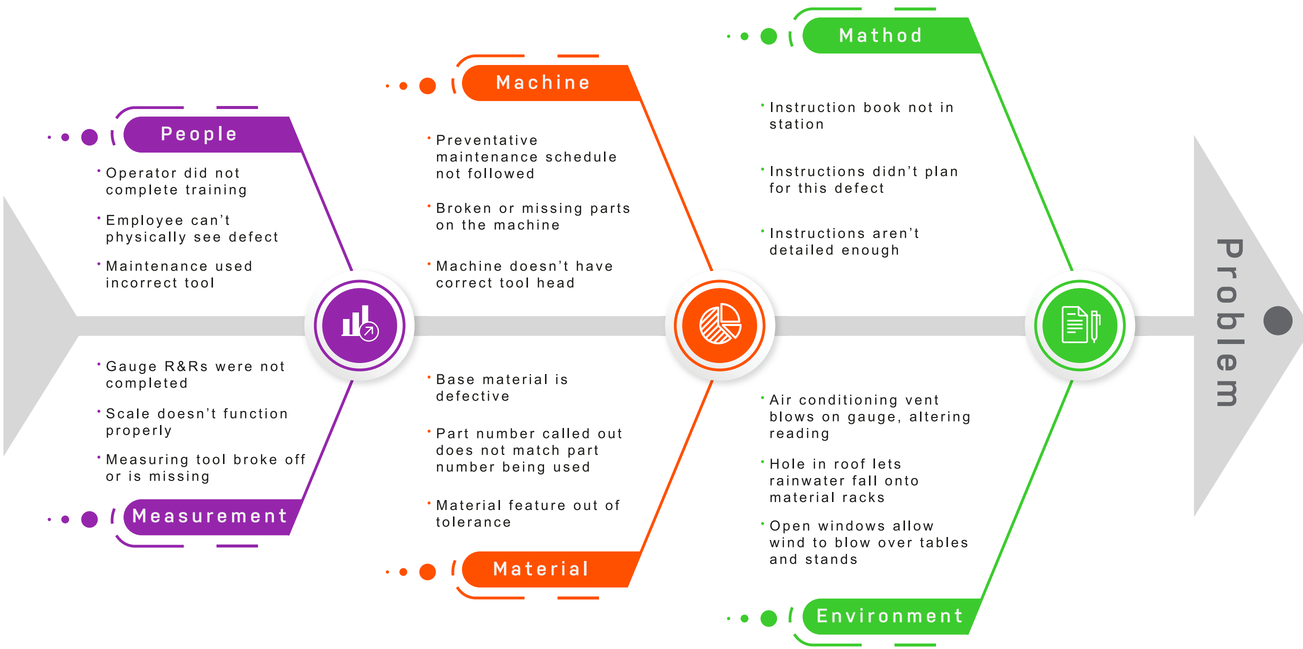
Popularized in the 1960s, the Ishikawa diagram was used as a basic tool of quality control by Kaoru Ishikawa at the University of Tokyo. It is considered part of The Basic SevenSeven Basic tools Tools of quality Quality control Control today.

Over time, it was nicknamed the fishbone diagram due to its resemblance to a fish skeleton laid on its side. At the mouth goes the problem itself. Each of the bones feeding into the spine of the fish represents a specific category of potential contributors to the problem.

While the categories can change, the most commonly used are:

- People
- Machine
- Method
- Measurement
- Material
- Environment

Under each category is where you add elements that could impact the process associated with that cause. It's worth noting that each category may also have various sub-causes as well.



People

This category is for anything related to the people associated with the process. Operators are the most common group in this category, but it can also include maintenance teams, quality control specialists and supervisors.

Potential causes in this category include:

- Operator did not complete training
- Employee can't physically see defect
- Maintenance used incorrect tool

Machine

This category is for all elements related to the machines used in a process. Depending on the process, this category could capture anything from pouring robots in a foundry to printers in a book shop.

Some examples of causes in this category are:

- Preventative maintenance schedule not followed
- Broken or missing parts on the machine
- Machine doesn't have correct tool head

Method

This category is for process documents and instructions. Here is where you would review any instructions used during the process being evaluated. Look at whether the instructions accurately describe the process, if they prevent a defect from occurring or even whether a picture is clear enough.

Examples of causes here could be:

- Instruction book not in station
- Instructions didn't plan for this defect
- Instructions aren't detailed enough

Measurement

This category of the fishbone diagram captures any techniques used to measure whether a part or process meets the desired quality standards. You might include information on scales, vision systems or human inspectors here, as well as sub-causes such as:

- Gauge R&Rs were not completed
- Scale doesn't function properly
- Measuring tool broke off or is missing

Material

This category captures the materials involved in a given process. Whether raw materials or inspection materials such as soapy water sprayed on a tire to detect leaks, anything added during a process can impact quality. In this area of the fishbone, you review every material that goes into a process to weigh its potential impact.

Potential factors in this category include:

- Base material is defective
- Part number called out does not match part number being used
- Material feature out of tolerance

Environment

This category is for relevant external factors at different points in the production process, including storage and the work area itself. For example, you might consider temperature, humidity or pressure when searching for a root cause. Problems in the plant that cause inconsistent environmental conditions could be the source of your troubles.

Here you might find problems in areas such as:

- Air conditioning vent blows on gauge, altering reading
- Hole in roof lets rainwater fall onto material racks
- Open windows allow wind to blow over tables and stands

A fishbone diagram is a simple yet powerful way to brainstorm potential causes of problems and how they interact. Using one during your next brainstorming session can help you narrow in on the root cause of problems, giving you a holistic look at quality issues and where to focus your problem-solving.

Once you've identified the root cause, the next step is eliminating the chance of recurrence. The corrective action is just the start, as it's essential to check back in on problems to ensure the fix is still in place. Plant floor audit software like EASE makes it easy, giving you the ability to easily add questions based on corrective actions and report on findings immediately.

This combination of problem-solving, corrective action and high-frequency audits is the key to continuous improvement, also providing a framework for a culture of quality.

CHAPTER 4

Scatter Plots

Let's say that you have a conveyor belt in your facility that keeps causing downtime, with maintenance fixing one specific conveyor belt over and over.

You use the 5 Whys Method to determine possible causes and find:

> Parts on the conveyor could be too hot
> The conveyor is old and not being serviced frequently enough
> Maintenance is not doing the repairs correctly
> Downtime is being called in error to cover for another problem

Of these possible causes, you want to know which ones have an impact on the problem. One way to assess this question is with a scatter plot.

A scatter plot is a graphical representation of the relationship between two variables, offering a look at how closely two features are related. Let's look at how to use a scatter plot to identify these relationships.

Choosing Variables

The first step in creating a scatter plot is choosing your independent and dependent variables. In other words, which process parameter (independent variable) is causing the problem (dependent variable)? These variables correspond to the x and y axis, respectively.

As you create your scatter plot, it's critical to choose variables that are as simple, measurable and as objective as possible.

Let's start with the first option on the list: Parts on conveyor could be too hot. If you wanted to test this idea, you might look at whether part temperature correlates with number of work orders on the conveyor.

Measuring Variables & Organizing Data

Now that you have chosen your variables, it's time to measure them, either via observing the process or pulling data from a digital source such as your part measurement system, maintenance system or process audit software.

Hour of Shift	Average Part Temp. (F)	# Work Orders for Conveyor
8-9AM	88	3
9-10AM	90	3
10-11AM	104	25
11AM-12PM	92	7
12-1PM	94	9
1-2PM	96	11
2-3PM	102	20
3-4PM	100	19
5-6PM	98	17

Chart Name
Y Values
X Values

Let's say your data looks like this:This is what you will use to generate your scatter plot. If your hypothesis is that the parts are too hot and damaging the conveyor, then increasing temperatures should correlate with more work orders.

Building Your Scatter Plot

Once you have your data collected, building the scatter plot and evaluating correlation is easy in a spreadsheet. In our example, you are looking at how many work orders happened at each temperature. That means temperature goes on your x-axis and number of work orders goes on your y-axis.

Evaluating the Results

In this example, we have a clear pattern. It is obvious that the data points trend upward. This means that there is a direct correlation between the temperature of the part and the number of work orders that are cut against the conveyor. This is solid evidence supporting your hypothesis that the heat of the parts is causing damage.

If you wanted to prove it further, you could do a linear regression in Excel to determine the R^2 value, which tells you how strong the correlation is. Correlation is defined as the degree to which the data fit a line on a graph.

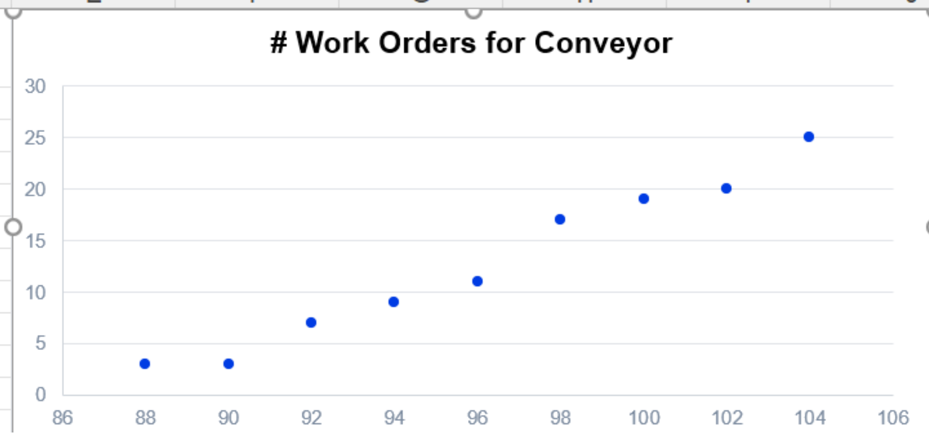
R^2, or the coefficient of determination, is a score of how well changes in x predict changes in y in your data. The closer to 1 the R^2 value is, the more predictable your data is.

Next Steps

Now that you have identified a correlation between part temperature and equipment failure, you have a data-based defense for attacking a possible root cause.

In terms of next steps, recall from earlier in the example that there were multiple items listed as possible contributors to defects. So far, we have only assessed one of them.

Temp of Part	# Work Orders for Conveyor
88	3
90	3
104	25
92	7
94	9
96	11
102	20
100	19
98	17



Other root cause analysis tools you might use to assess the other items listed from the 5 Whys Method include:

- FMEA: For testing whether conveyor is being serviced frequently enough
- 5 Whys: For evaluating whether maintenance is not doing the repairs correctly, conducting another 5 Why down a different path
- Fishbone Diagram: To determine whether downtime is being called in error to cover for another problem

Scatter plots are useful for data sets of varying sizes to show correlation between an outcome and a potential cause. However, it's important to note that correlation doesn't equal causation. That is, just because there is strong correlation between two variables doesn't mean that you've found the true root cause.

Ultimately, you'll want to use scatter plots alongside the other root cause analysis tools in this guidebook to determine where to apply your facility's resources for continuous improvement. Looking at a problem from many different angles is the key to solving those problems—and developing permanent fixes that prevent defects from the start.

CHAPTER 5

Failure Mode and Effects Analysis (FMEA)

Most people use the fundamentals of a failure mode and effects analysis (FMEA) on a daily basis without even realizing it.

On a basic level, this root cause analysis tool is about thinking through everything that could go wrong, the impact on customers and what steps can prevent failures.

Let's look at the basics of creating an FMEA, including how to set one up and a real-life example of how to use it.

What is an FMEA?

An FMEA is a structured, empirical approach to understanding the potential impact of something going wrong in a process. Each individual opportunity to go wrong is called a failure mode.

Each failure mode is assessed for three factors: severity (S), occurrence (O), and detection (D). These scores combine to produce a Risk Priority Number (RPN), and that score is the ranking system that you use to determine which problems to focus on first.

How to Set Up an FMEA: Current State

An FMEA has two sections. The first focuses on creating a scorecard for the current state, including potential causes and existing controls, and the second part focuses on corrections.

In the first part, each failure mode goes on its own line. Severity (S), occurrence (O), and detection (D) are scored on a scale from 1 to 10 based on the team's judgement. For each score, 1 would be the best–case scenario and 10 is the worst.

- Severity represents how bad the impact of a failure would be, ranging from no impact to catastrophic
- Occurrence represents how often the failure occurs, ranging from extremely unlikely to inevitable
- Detection represents how likely you are to catch the failure

FAILURE MODE AND EFFECTS ANALYSIS TEMPLATE

Process	Failure	Effect	S	Potential Causes	O	Controls	D	RPN

How to Set Up an FMEA: Corrections

The second half of the FMEA is used to assign necessary corrective actions to the appropriate people to prevent problems identified in the first section.

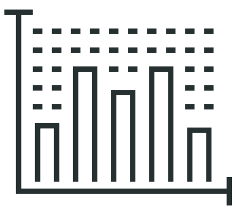
Know that not all problems have obvious solutions. Sometimes the action is simply to determine next steps.

An FMEA Example

FMEAs are used before things go wrong to prevent quality failures. In this example, we apply the FMEA process to a drive into work.

The first step is breaking down the process into smaller bites (although some teams may prefer to do this as they go). What are some sub-processes of driving into work?

- Backing out of the driveway
- Driving through town
- Merging onto a highway
- Passing through a toll bridge
- Navigating traffic jams
- Parking at the office



Each one of these sub-processes has their own failure modes. What can go wrong when backing out of the driveway? What can go wrong when merging onto the freeway? These are the questions that you ask yourself every day, consciously or not.

Failure Modes

An FMEA allows you to dig into each item in great detail. What can go wrong when backing out of a driveway?

1. Hitting another car
2. Running over a toy
3. Hitting a person
4. Being hit by another car

From here, choose one failure mode and drill down. If you hit another car, what is the effect? How severe will it be? What might have caused it? How often might you hit another car? What could you do to prevent it? How likely are you to notice?

Those questions lead through the full FMEA and end with calculating the RPN. Once you have scored everything, multiply the three numbers together to get the RPN. This overall score lets you rank potential problems.

Assessing FMEA Results

Now that the first half is done, it's time to evaluate and correct. With such a high RPN, it's important to contain this problem. The goal is to implement controls that will bring down any of these scores.

What action can you take to reduce the severity of hitting another car? Sometimes, you can't do anything about severity. What can you do about occurrence? Can you reduce the likelihood that you will hit another car?

Perhaps training could help. Increased awareness and diligence could go a long way. Every control you add will help bring down the RPN. What could you do to increase detection? How could you help yourself know when there is another car behind you?

Corrections

At this point, an action can be assigned to a responsible person. From here, the responsible person should pick up the project, make their changes, and update that information on the FMEA itself.

Process Name: Driving into work **Date: 4/28/2021**

Action	Responsible	Actions Taken	S	D	O	RPN
Install backup camera	Johnson	Backup camera installed on 4/28/2021	9	3	1	27

To create a closed-loop corrective action process, you'll need to check back to verify the correction was implemented and held in place. This means updating plant floor audit checklists, either on paper or in your mobile audit software.

FMEAs can seem complicated at first, but as you use them, they become second nature. The objective is to reduce overall RPN scores as far as possible by implementing controls that reduce the severity and occurrence, or that increase the detection of a potential failure. Referring to our driveway example, something as simple as parking in the driveway backwards could help prevent hitting another car.

Not only does this process help you develop solutions, it also provides empirical data to support your decisions.

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Conclusion

Root cause analysis is fundamental to the entire quality process, helping you focus your time, energy and problem-solving resources on the most effective solutions. Different root cause analysis tools are used different situations, and companies often must use multiple tools in combination to find the real root cause of a problem.

A simple problem might be easily solved with a 5 Why, while thornier issues might require a fishbone diagram, scatter plot and FMEA to get to the root of the issue.

No matter what path you take, it's essential to close the loop the findings within your quality processes as a whole. That could mean updating FMEAs based on findings from a 5 Why, or updating plant floor audit questions to verify effectiveness. The bottom line is that you have to do more than the box, using root cause analysis within a corrective action process designed to solve problems permanently. Plant floor audit software can help, providing a simple, intuitive platform for uncovering risks, gathering data and verifying corrections.

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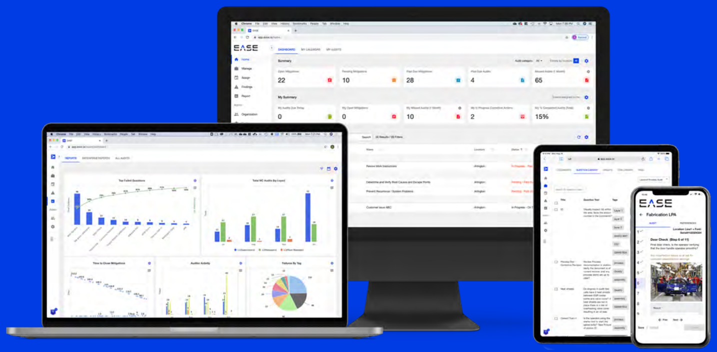

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