Problem Solving Through Root Cause Analysis

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Problem Solving Through Root Cause Analysis: Choosing Effective Processes and Tools

For manufacturing and packaging operations, unplanned downtime on the production line generates direct and indirect costs that can seriously impact productivity and profitability. We provided guidance for calculating and managing these costs in the Videojet white paper, *Printer Availability: Driving OEE and Uptime on Packaging Lines.* Here, we'll be taking a closer look at processes for determining root causes of unplanned downtime, and how to devise countermeasures that improve the Overall Equipment Effectiveness (OEE) and profitability of your operation. To minimize unplanned downtime, companies need to execute four critical steps:

- Design and configure the line to meet quality and output requirements
- Select the right equipment for the application
- Maintain the equipment properly during its life
- Clearly define measures and processes to continuously improve the operations of the equipment

While the first three steps may seem like obvious OEE requirements, it's not uncommon for manufacturers and producers to make near-term or expeditious decisions on equipment selection and maintenance in an attempt to save time and expense. All too often, the result is that they pay a higher price in the long run as a result of unplanned downtime.

Even when implementing the first three steps correctly and consistently, virtually any manufacturer will still experience some unplanned downtime with any given piece of equipment. That's where the fourth step comes in. To maximize OEE, you need to adopt clearly defined measures and processes for continuously improving the performance of your equipment and its operation. Although we're calling this the fourth step, it's more appropriate to think of it as an ongoing journey. That journey is the focus of this paper.

To chart a path of continuous improvement, you need guideposts to help you see where you are today in relation to where you want to be, and to continually mark your progress. That means you need a way to quickly determine the source of existing and potential issues, analytical tools to discover the root causes of these issues, and the ability to formulate and implement sustainable countermeasures.

In lean manufacturing, root cause countermeasure tools are often used to help perform the necessary discovery and analysis, and to provide the insight needed to develop an effective and permanent solution. This approach is sometimes referred to as the Problem Solving (PS) method.

Videojet has devoted considerable resources to refining the PS method as a key tool to drive our teams through a continuous cycle of change and improvement.

As an essential part of that cycle, our kaizen-based approach to PS has worked well, and we'd like to share key features of the method to help you focus and accelerate your own problem solving. After an overview of the Videojet PS method, we'll provide an example of how the method can be used to perform root cause analysis and implement sustainable countermeasures to address unplanned downtime in an ink jet printer.

Problem Solving: The Basics

Good problem solving is an iterative effort that requires strong leadership, good teamwork and relentless follow-through. If it were easy, you wouldn't need to spend time diving deep in an effort to understand the root causes and solutions. You'd simply solve the problem.

The acronym DIVE (Define, Investigate, Verify and Ensure) captures the key elements of the process.

Time Spent

70%

Define the Problem
Articulate the problem statement
Determine if the gap is from a caused problem or a created problem
Determine rationale to solve the problem

Investigate to Drive to Root Cause
Go to source of issue to narrow focus to 3 actual causes
Drive to root cause – "5 whys"
Go to the source of issue to get evidence and facts

30%

Verify and Implement
Identify and evaluate possible countermeasures
Test selected countermeasure and validate effectiveness
Implement and verify closure of the "gap"

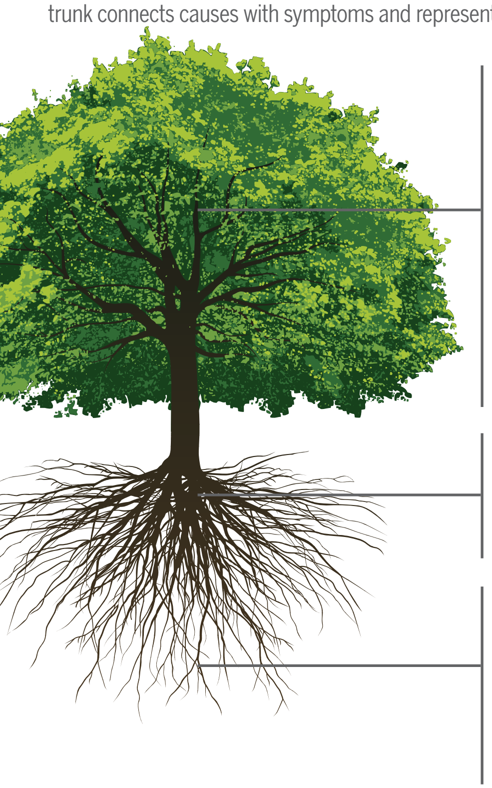
Ensure Sustainment
Focus on the critical few countermeasures
Identify owner and additional resources
Go to source of issue to measure results

Define the Problem

The entire process depends on applying critical thought to correctly define the problem upfront. It's easy to confuse the true problem with the symptoms of the problem and the presumed causes of the problem. This can lead to treating the symptoms without addressing the cause, or misidentifying the cause altogether and thereby applying ineffective countermeasures. If you start in the wrong place, you will never reach your destination – a sustainable solution to your root issue.

In addition, your position in the organization and your previous problem-solving experiences can influence how you interpret the current problem. A psychologist might refer to this as "confirmation bias" – the tendency of people to see what they expect to see. In the PS method, this is called Point Of Recognition. For example, an employee on the factory floor investigating a problem at the root level might tend to conflate the problem with its causes, while an operations director might define the same problem in terms of its symptoms.

It can help to think in terms of the structure of a tree, with the roots representing several possible causes and the branches representing several symptoms. The trunk connects causes with symptoms and represents the true problem.



Symptoms:
The result or outcome of the problem (obvious)
Sweating

The Problem:
The gap between reality and the goal or standard
Fever

Causes:
The underlying "roots" – a system below the surface that is the true source of the problem (not obvious)
Virus

Effective problem solving must focus on the one true problem. There may be multiple causes and symptoms, and multiple people focusing on each, but until you have identified a single, true problem you can't begin to solve it.

In the words of inventor Charles Kettering, "A problem well stated is a problem half solved."

The Four Essential Elements

Every useful problem definition includes these elements. You must review and specify all four:

Goal/Standard = Where you want to be. The desired state.

Actual = Where you are now.

Gap = The difference between the goal and actual.

Trend = The pattern or extent of the problem. How severe is it? How long has it been occurring? Is it local or global in scope?

Incorrect Paths

When defining the problem statement, be careful to avoid these missteps:

- The problem statement addresses more than one problem.
- The problem statement assigns a cause.
- The problem statement assigns blame.
- The problem statement offers a solution.
- The run chart is in units of measure that are unrelated to the problem statement.
- The problem statement is missing one of the four essential elements: goal/standard, actual, gap, trend.
- Resources are misaligned and working on the wrong problem.
- The problem lacks rationale.

Signposts of Success

You have defined the problem well when you can say:

- The problem statement is clear and actionable.
- The team has come to a consensus on the problem statement.
- The team agrees on rationale of why the problem and its solution are important.
- The problem is in your area of control, so the team can take effective responsibility for solving it.

Investigate to Drive to Root Cause

The nature of problems is that they tend to appear, initially, as large obstacles with unclear boundaries. Unless you narrow the focus, your team is likely to meander without a clear purpose and direction. A properly conducted analysis concentrates strictly on the problem at hand – not its effects or presumed causes – and flows from point to point along a clear, logical path. This path proceeds from Point of Recognition (POR) to Point of Occurrence (POO) to Point of Cause (POC) and ultimately to root causes.

Once you have determined and clearly defined the problem, you can begin to analyze the causal chain. In most cases, you'll find that the roots of the problem tend to expand in various directions as you trace them, just like a root system of a tree. In a natural attempt to be thorough, most people attempt to follow all or too many of the roots. But that can be counterproductive. A better approach, usually, is to ignore roots with the least impact on the problem and truncate those not supported by any available data. Selective pruning makes your analysis more efficient and effective.

Keep in mind the following:

- One problem may have more than one root cause.
- One root cause may be contributing to many problems.
- When the root cause is not addressed, expect the problem to reoccur.
- Prevention is the key!

For an efficient investigation, concentrate your efforts on a few well-defined areas. A step-by-step approach, such as the Pareto method can help (see sidebar for details). Using a focused and methodical approach helps you:

- Narrow your investigation to focus on where the root causes are.
- Determine the critical few root causes that can be addressed.
- Formulate hypotheses that can be objectively tested.
- Correlate individual causes to impacts and their relative severity.
- Identify the causes that can be corrected in the shortest time to provide the greatest benefits in increased uptime and performance.

Having identified the most fruitful areas for further investigation, you can take a deeper dive into the root causes most responsible for the gap between the performance you want to achieve and the performance you're actually getting.

One method for getting at the root of a problem quickly is the "5 Whys" technique, which helped Toyota transform its production systems in the 1970s. The "5 Whys" technique involves simply asking "why?" (or related questions – what, where, when, who, how?) at least five times, diving deeper each time from the problem to the root cause. For example:

Problem Statement: Fab units/hr Plan: 100/hr vs. Actual: 50/hr, trend declining

Why? We are not able to make enough parts each hour

Why? We are losing production opportunities

Why? Losing time

Why? Cycle time losses

Why? Loading machine takes too long

Why? Operator walks 5 feet for material

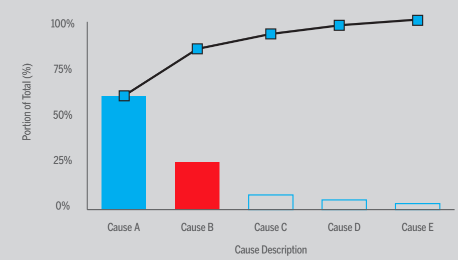
To verify that the analysis is correct, you should be able to propose a countermeasure to the root cause and apply the word "therefore" to verify that the countermeasure addresses each cause in the chain. In this example, moving the material closer to the operator (the countermeasure) reduces walking. Therefore, the machine can be loaded faster. Therefore, cycle time losses are reduced. Therefore, increased time is available. And so on.

The Pareto Method: A Brief Overview

Businesses have often used the Pareto method to help determine the root causes of all types of problems, and this method is well suited to solving problems of unplanned downtime in manufacturing and packaging environments. The Pareto method, also known as the 80-20 rule, posits that 80% of a problem's impacts generally result from only 20% of its causes. Based on this principle, the Pareto method provides a simple technique for quantifying the severity of a problem and identifying the most important causes to address.

Using the Pareto method, causal impacts are often represented in a bar chart:

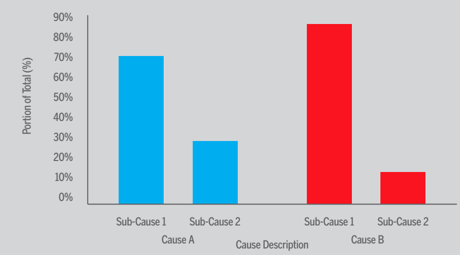
Level 1 - Areas of Investigation



In this chart, the size of each bar shows its contribution to each cause of the problem, and the line plots the operational improvements that can be achieved by addressing each cause. Cause A and cause B clearly have the greatest impacts, and removing them first brings the greatest potential for improvement.

Analysis of leading causes often reveals deeper levels of causation, and upon further investigation these sub-causes can also be ranked according to their relative contribution to the problem:

Level 2 - Areas of Investigation



It's important to note that the "5 Whys" technique can break into multiple chains when a particular "why?" has multiple answers. This is the time to apply the Pareto method and determine which pathway has the greatest effect in causing the performance gap. When choosing between two courses of action, it's better to address the causes with an 80% impact on the problem first, before dealing with causes that have a lesser impact.

Verify and Implement Countermeasure

Once you have identified the true root cause, problem-solving becomes much easier. You now have the information you need to propose, verify and implement countermeasures. These can be temporary countermeasures intended to get you back on target quickly, and/or permanent countermeasures that deliver sustainable improvement. Often companies will do both, implementing a temporary countermeasure to address the problem in the short term while working on a permanent countermeasure that will provide a sustainable solution for the long term.

With a clear understanding of the problem, its root causes and their relative impacts, the team should start by brainstorming a set of potential countermeasures and then work together to identify the approaches most likely to be effective.

From the pool of potential countermeasures, narrow your focus to the best two or three based on:

- Ease of implementation.
- Impact to the business.
- Cost.
- Area of control.

Evaluating the chosen countermeasure should be done through observational testing. Consider performing this evaluation on a limited test case rather than as part of a full implementation. You need a follow-up plan with recommended adjustments if you don't get immediate results – or for a larger rollout of the solution if you do. Either way, observational testing provides you the opportunity to understand and quantify the relationship between the validated root cause and the selected countermeasure – and to identify and address potential failure points – without putting the entire organization at risk.

If measurable improvement can't be quickly verified, it's time to investigate whether the countermeasure was implemented correctly. If it was, but you're still not seeing improvement, you may need to test another countermeasure.

Once you're confident that the chosen countermeasure is effective, you can implement it throughout the entire production environment. But that's not the end of the process. You should continue to monitor the effectiveness of the countermeasure to ensure the problem won't recur, and you should continue to identify additional opportunities for improvement.

Avoiding "5 Whys" Pitfalls

Keep in mind that the"5 Whys" technique is not a blame game. When addressing process-oriented questions, each "why?" should be focused on uncovering a lack of process, an ineffective process and/or a failure to execute a process. Also keep in mind that the "5 Whys" technique is just one method, designed for quick analysis of relatively simple problems. More complex problems may not be amenable to this approach. If you don't quickly come to a clear answer, you may need to turn to more advanced problem solving techniques.

Ensure Sustainment

Not having a sustainment plan is planning to fail. Using the Pareto method, focus on the countermeasures that have the highest potential for failure – those that address the 20% of root causes that contribute to 80% of the problem. These countermeasures should be evaluated daily or weekly, while less critical countermeasures can be evaluated less often.

Every sustainment activity should have an owner, a formal process for data measurement and reporting, and resources allocated to ensure timely evaluation and improvement. The owner's job is to ensure that countermeasures are continually applied and verify their effectiveness. If changing employee behavior is part of the countermeasure, it's especially important to manage resistance and monitor compliance. Useful tactics include:

- Asserting the need for improvement and being willing to engage in tough conversations.
- Identifying where you or others are stuck.
- Staying focused on the objective.
- Looking for signs of resistance.
- Making it safe for resisters to engage in open, honest dialog.
- Working to gain consensus.
- Helping people move from consensus to action.
- Rewarding success.
- Asking for feedback from the team, internal stakeholders and customers to discover further avenues for improvement.

The key to all of this – from technical fixes to employee buy-in – is having high-quality, actionable information about the problem and its root causes. Actionable information is what allows you to develop and fine-tune effective countermeasures, communicate necessary changes to the organization and objectively measure results.

Actionable Information: The Videojet Approach

Data about equipment availability and causes of unplanned downtime can come from many sources. However, evaluating its significance and correlating it with other available data to provide a basis for action can be a challenge. At Videojet, we believe there's much more that industrial equipment suppliers can – and should – do to support quick and effective root cause analysis for manufacturers and producers.

Beyond providing raw data about the equipment's function and performance, technology is available to help users see data in its full context for improved decision support. In other words, the machine itself should help convert raw data into actionable information.

Videojet is pioneering this capability with innovative productivity tools integrated with our continuous ink jet printers. We believe these tools provide an excellent model for the data analysis capabilities that equipment manufacturers should be building into their products, and that buyers should look for in new equipment.

The newest Videojet continuous ink jet printers – the new 1550 and 1650 printers – have a vast array of drill-down capabilities that can help producers and manufactures achieve sustainable process improvements through discovery of true root causes – whether those causes are related to specific printer functions, operator errors or a combination of both.

Let's look at a simple example of how this process works. Imagine a problem that manifests itself as a gap between the actual output of a production line and the production goal. After initial evaluation using the Pareto method, the team has identified two primary areas for root cause analysis. One contributing cause is that key raw materials are not always available when they're needed. The other is that coding equipment is not always available.

Neither of these contributing causes is a root cause. The team will have to do further analysis to get to the root of the problem and solve it. Although the raw materials themselves can't tell you why they're not available, Videojet continuous ink jet printers can give some highly specific and valuable clues as to why the printer was not available. Here's how.

Top-level Availability statistics

Videojet continuous ink jet printers report Availability statistics. To make these statistics immediately useful, they can be accessed easily on the touchscreen interface:

Top-level availability statistics are shown by time period with configurable production time proxy.

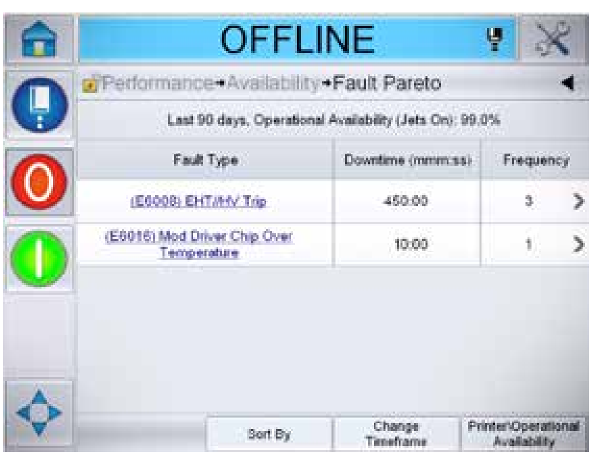
To help identify trends, Printer Availability is displayed for various time periods. In this case, the system's event log is configured to display Availability percentages for the most recent 30 days, the most recent 90 days, the current month and several past months.

Also notice that Availability percentages are broken down by Printer Availability, meaning that all printer systems are functioning properly, and Operational Availability, meaning that the printer is free from all errors, including operational errors such as running out of ink or a printhead that needs to be cleaned. To best replicate your planned production time, Operational Availability can be configured to track either Power-On time (the printer is turned on) or Jets-On time (ink is cycling and the printer is either printing or ready to print on demand). While many Availability reporting systems capture statistics for when the equipment is powered on and functioning properly, the addition of configurable Operational Availability statistics can be invaluable in helping to determine whether downtime is due to a printer hardware problem or an operator error, and how much the problem is affecting your productivity.

To find out more about the causes of downtime, simply touch any of the reported Availability figures to drill down to the specific faults involved. Let's walk through two examples.

Drill-down example 1

Selecting the 99.0% Operational Availability figure reported for the last 90 days, you learn that the system recorded two types of faults: three instances of a breaker trip due to extra-high tension/high voltage, causing 450 minutes of downtime, and one instance of a mod driver chip over-temperature fault, causing 10 minutes of downtime:



Drill down to discover specific faults, how often they have occurred and how much unplanned downtime they have caused.

You can learn more about the nature of each fault by selecting the Fault Type, and you can review the Frequency column to learn more about each occurrence of the fault. The Pareto principle suggests you should begin by investigating the fault with the most occurrences and most downtime. What causes an EHT/HV trip and why has it happened so often?

The Fault Type information tells you that EHT trips are most often caused by a dirty printhead, and selecting "3" in the Frequency column gives you information about the time and duration of each event. In this case, the time of each fault provides a clue about why it's occurring:

Drill down again to view the time and duration of each fault event.

While you could drill down further into the particulars of each unplanned downtime event, this screen shows a clear pattern that could lead you to the root cause and a solution. It's apparent that the fault is happening at regular intervals – basically, every thirty days. The cause of the problem may simply be that you're not doing preventive cleanings of the printhead often enough. If that's true, an effective countermeasure may be simply to institute a schedule for cleaning the printhead every 25 days.

To confirm this root cause analysis and the effectiveness of the proposed countermeasure, you need to review activity logs and work with your line personnel to understand standard work practices and possible deviations.

Root Causes: Printhead cleanings too infrequent; operators not adequately trained.

Countermeasures: Schedule 25-day planned printhead cleaning. Train staff in preventive maintenance procedures. Have shift supervisors proactively monitor the staff to help ensure all preventive maintenance activities are completed properly.

Sustainable Action: Have the area manager monitor logs on a weekly basis to help ensure a reduction in EHT/HV faults and check for other downtime events and associated faults.

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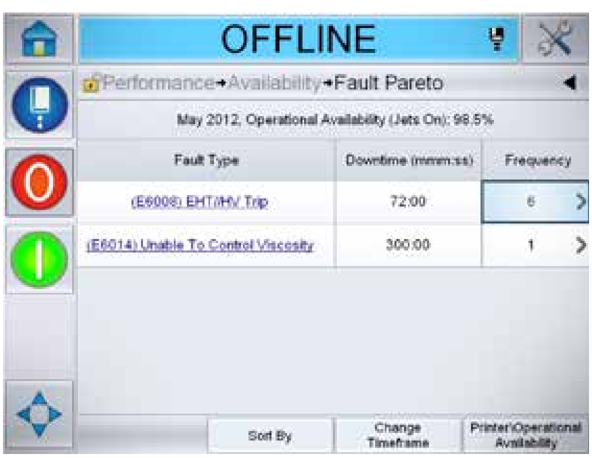
Drill-down example 2

Selecting the 98.5% Jets-On Operational Availability figure reported in May, you learn that a series of EHT/HV Trip faults led to unplanned downtime. It's the same type of fault as the previous scenario, but this time it has a different cause. Drilling down from the Operational Availability metric reveals that the fault occurred six times, with a total downtime of 72 minutes:



Drill down to see the faults that occurred in May, the frequency of occurrence and the total downtime.

There was also an Unable to Control Viscosity fault during this same period leading to 300 minutes of downtime. But since the EHT/HV Trip is happening repeatedly, it might happen again and the Pareto principle suggests investigating it first. Drilling down further reveals an important clue about the root cause:

The event time and duration here point to a different cause from the previous example.

All the EHT/HV Trip faults occurred on May 5th during the same shift, 12 minutes apart.

EHT/HV Trip faults are almost always the result of a dirty printhead. In this case, the operator isn't cleaning the printhead, but is simply attempting to clear the fault by restarting the printer.

With each restart, make-up fluid is added to the ink supply. Further investigation would reveal that the Unable to Control Viscosity fault happened just after this series of restarts, suggesting that the ink supply became flooded with too much make-up fluid.

You now have the information you need to identify the root cause of both faults and take corrective action to help prevent them from happening again:

Root Cause: The operator on third shift did not know how to clean the printhead, instead performing multiple restarts in an attempt to clear the EHT/HV Trip fault. These restarts flooded the ink with make-up fluid, resulting in the Unable to Control Viscosity fault.

Countermeasure: Train operators on the cause of EHT/HV Trip faults and how to clean the printhead. Explain the purpose of make-up fluid and why too many consecutive restarts can lead to extended downtime due to flooding.

Sustainable Action: Review the Event Log for each shift to help ensure the problem doesn't recur.

From Problem Solving to Continuous Improvement

Our intent in this white paper has been to give you a framework for solving specific problems through root cause analysis, as well as inspiration for applying problem-solving techniques rigorously to continuously improve the uptime and productivity of your operation. The same philosophy of continuous improvement drives our product development, as exemplified by the problem-solving capabilities we've built into the user interface of our new 1550 and 1650 continuous ink jet printers.

The industry needs to continue to evolve toward more effective problem solving for more reliable uptime. Count on Videojet to take a leading role in this effort as we continue to work with you to bring the best possible uptime and performance to your daily operations.

As a Danaher company, Videojet uses the Danaher Business System (DBS), which is a process for continuous improvement. Fueled by Danaher's core values, the DBS engine drives the company through a never-ending cycle of change and improvement: exceptional people develop outstanding plans and execute them using world-class tools to construct sustainable processes, resulting in superior performance. Superior performance and high expectations attract exceptional people, who continue the cycle. Guiding all efforts is a simple philosophy rooted in four customer-facing priorities: quality, delivery, cost and innovation.

As part of DBS, Videojet has successfully used tools like Problem Solving as discussed in this whitepaper. We use DBS to guide what we do, measure how well we execute, and create options for doing even better - including improving DBS itself.

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