TWO

Problem Analysis

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The Conditions and Skills of Problem Solving

People like to solve problems. While people in organizations enjoy the rewards that go with success, they also enjoy the process that produces success. Regardless of their organizational level, they will not only accept but will also seek problem-solving opportunities as long as four conditions exist:

- ➢ They possess the skills needed to solve the problems that arise in their jobs.
- ➢ They experience success in using those skills.
- ➢ They are rewarded for successfully solving their problems.
- ➢ They do not fear failure.

The converse is equally true. People will avoid problem-solving situations when they are unsure of how to solve their problems, when they do not experience success after trying to solve a problem, when they feel that their efforts are not appreciated, and when they sense that they have less to lose either by doing nothing or by shifting responsibility. This chapter is concerned with the first condition: *the skills that make problem-solving behavior possible*. The other conditions for habitual, successful problem solving will be discussed in subsequent chapters.

Problem Analysis provides the skills needed *to explain any situation in which an expected level of performance is not being achieved and in which the cause of the unacceptable performance is unknown*. If "any situation" seems too strong a phrase, remember that we are concerned with *the way in which information is used to approach deviations in performance*. These deviations may appear in the performance of people or the performance of systems, policies, or equipment, that is, anything in the work environment that may deviate from expected performance with no known cause. As long as this structure applies, the techniques of Problem Analysis also apply.

In this chapter, we will explain and demonstrate Problem Analysis by examining a problem that occurred in a production plant owned by one of our clients. We have selected this problem as a case vehicle because it is concrete and easily understood, therefore ideal for introducing the techniques of Problem Analysis. In Chapter Three, we will describe the use of these techniques in a variety of industries, at differing organizational levels, and over a wide spectrum of problem situations.

Cause and Effect

Problem solving requires cause-and-effect thinking, one of the four basic thinking patterns described in Chapter One. A problem is the visible effect of a cause that resides somewhere in the past. We must relate the effect we observe to its exact cause. Only then can we be sure of taking appropriate corrective action—action that can correct the problem and keep it from recurring.

Everyone has experienced the "solved" problem that turns out not to have been solved at all. A simple example is the car that stalls in traffic, goes into the shop for costly repair, and then stalls again on the way home. If the cause of the stalling is a worn-out distributor and the action taken is a readjustment of the carburetor, then the car will continue to stall. Superior problem solving is not the result of knowing all the things that can produce a particular effect and then choosing a corrective action directed at the most frequently observed cause. Yet this is the way most people approach problems on the job. Problem Analysis is a systematic problem-solving process. It does not reject the value of experience or of technical knowledge. Rather, it helps us to make the best use of that experience and knowledge. Our objectivity about a situation is often sacrificed under pressure. When a quick solution to a problem is required, it is too easy to rely on memories of what happened in the past, on the solution that was successful once before, or on the remedy that corrected an apparently similar problem. This is the most common approach to problem solving, and problem solving by extrapolation is a tough habit to break despite its relatively poor payoff in appropriate, lasting corrective actions. A chief purpose of this chapter and the next is to demonstrate that the habit can be broken. Through the experiences of people in our client organizations, we will show that the effort required to adopt a systematic approach to problem solving is small in light of the results that follow.

The Criteria That Define a Problem

The following are typical examples of problems. They meet our definition of a problem because in each one an expected level of performance is not being achieved, and the cause of the unacceptable performance is unknown.

> "From the day we introduced the computer, we've had nothing but trouble in getting our inventories to balance. I just don't understand it."
>
> "Emory Jackson was referred to us as an outstanding engineer, but he certainly hasn't fulfilled expectations in this department."
>
> "Our Number Eleven paper machine never produces more than 80 percent of its design capacity, no matter what we try."
>
> "Some days we meet our schedules without any trouble. Other days we can't meet them at all. There just doesn't seem to be any good reason for the discrepancy."
>
> "The system worked well for months. Then, in the middle of the morning three weeks ago, it went dead. It's still dead, and we don't have the slightest idea of what happened."

Despite disparities in content, seriousness, and scope of these five examples, they all indicate a degree of performance failure, confusion or total lack of understanding about its cause, and the need to find a correct explanation.

There are other kinds of problem situations that do not meet our specific definition. For example:

> "There is no way we can meet our deadline on the project with our present staff and no way we can get authorization to bring on anyone new. This is a serious problem. . . ."

This statement represents the need for one or more decisions. It does *not* represent a deviation between expected and actual performance that is of *unknown* cause. In this example, resolution will consist not of an explanation as to why the situation arose but of a choice. Those concerned must identify some course of action that can produce satisfactory results under less-than-optimal conditions.

Compromises will probably be identified. Objectives for meeting the goal may have to be reviewed, reshuffled, or altered. Any number of potential actions may be considered. But the cause of the difficulty is known all too well. Decision Analysis, which is presented in Chapters Four and Five, is useful for resolving this kind of dilemma. A decision requires answers to the following questions: "How?" "Which?" "To what purpose?" A problem always requires an answer to the question "Why?"

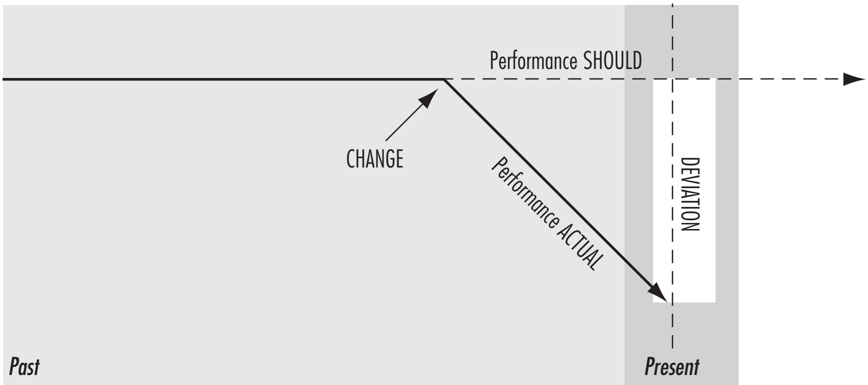
The Structure of a Problem

A performance standard is achieved when all conditions required for acceptable performance are operating as they should. This is true for everything in the work environment: people, systems, departments, and pieces of equipment. If there is an alteration in one or more of these conditions—that is, if some kind of change occurs—then it is possible that performance will alter, too. That change may be for better or for worse. Sometimes conditions improve, positive changes occur, and things go better than expected. But an unexpected rise in performance seldom triggers the same urgent response as an unexpected decline. The more serious the effect of the decline, the more pressure there is to find the cause and do something about it.

We may visualize the structure of a problem as shown in Figure 1.

FIGURE 1

STRUCTURE OF A PROBLEM

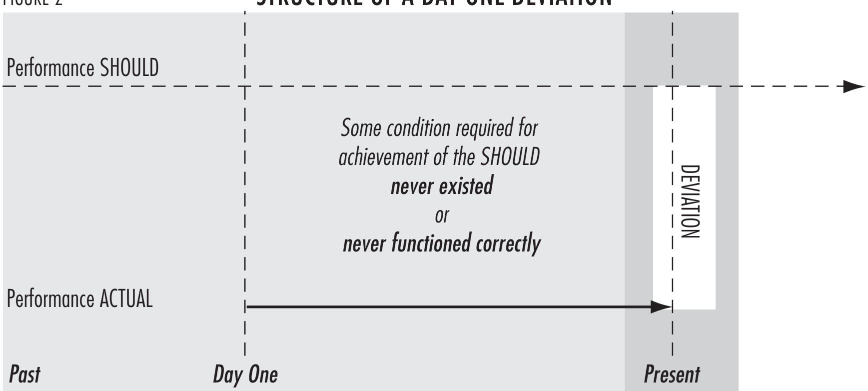


If performance once met the SHOULD and no longer does, then a change has occurred. At the outset of problem solving, we do not know exactly what that change consisted of or when it occurred.

The search for cause usually entails a search for a specific change that has caused a decline in performance. In some cases, however, a negative deviation in performance—a so-called Day One Deviation—has always existed. An example is an equipment unit that "was never any good *from the day it came on line....*" In this instance, using our terminology, ACTUAL has always been below SHOULD. This kind of problem can be visualized as shown in Figure 2.

FIGURE 2

STRUCTURE OF A DAY ONE DEVIATION



The Process of Problem Analysis

Both kinds of problems—a current deviation from formerly acceptable performance and a performance that has never met expectations—can be approached through the techniques of Problem Analysis.

The techniques of Problem Analysis are divided into these activities:

- State the problem.
- Specify the problem.
- Develop possible causes from knowledge and experience or distinctions and changes.
- Test possible causes against the specification.
- Determine the most probable cause.
- Verify assumptions, observe, experiment, or try a fix and monitor.

Case History: The Leaking Soybean Oil Filter

The history of our true case vehicle is a necessary prelude to demonstrating the Problem Analysis techniques. The Case of the Leaking Soybean Oil Filter may never make a best-selling mystery, but, as with most real-life mysteries, to the people who had to live with it, explain it, and correct it, it was of far more interest than any best-seller. Although Problem Analysis was used *after* the explanation had been arrived at (quite accidentally), it demonstrated—to the people who had worked on the problem inefficiently and unsuccessfully for several days—that a systematic investigation process would have produced the correct explanation within a matter of hours.

Our client is a major food processor. One of the company's plants produces oil from corn and soybeans. The five units that filter the oil are located in one building. On the day the problem was first observed, a foreman rushed into his supervisor's office: "Number One Filter is leaking. There's oil all over the floor of the filter house."

The foreman guessed that the leak was caused by valves loosening up from vibration. This had happened once before. "Number One sits right next to the main feedwater pump and gets shaken up more than the other four filters." A mechanic tried to find the leak but couldn't tell much because the oil had already been cleaned up. The lid fastener looked all right. After examining the pipes, valves, and walls of the filter chamber, the mechanic concluded that the oil had spilled from another source.

The next day there was more oil. Another mechanic traced the leak to the cleanout hatch, but that didn't help much. Why should the cleanout hatch leak? It looked perfectly all right. Just to be on the safe side, he replaced the gasket even though it looked new. The hatch continued to leak. "Maintenance people just aren't closing it tight enough after they clean it out," someone volunteered. "There are a couple of new guys on maintenance here since the shifts were changed around last month. I wonder if they're using a torque wrench like they're supposed to. This happened to us once before because somebody didn't use a torque wrench." No one could say for sure.

The next day an operator slipped on the oil slick floor and hurt his back. The cleanup task was becoming more than irksome, according to some outspoken comments overheard by the foreman. A few people began grumbling about promises made at the last safety meeting to improve conditions in the filter house. Two days later the plant manager got wind of the situation, called in the supervisor and the foreman, and made it clear that he expected a solution to the oil-mess problem within the day.

That afternoon someone asked, "How come the gasket on the Number One Filter has square corners? They always used to have rounded corners." A quick check of the filters revealed that the other four filters still had round-cornered gaskets. This led to the discovery that the square-cornered gasket on the Number One Filter had been installed the evening before the leak was first noticed. It had come from a new lot purchased from a new supplier who charged 10 cents less per unit. This led to the question "How can they sell them for 10 cents less?" and to the subsequent observation "Because they don't work."

The new gasket was inspected and compared with the old gaskets. It was easy to see that the new one was thinner and uneven. It was equally clear that this gasket had never been designed to be used on this kind of filter unit. It would always leak. It should never have been installed. Additional gaskets were purchased from the original supplier and installed. The leaking stopped.

Looking back at the problem, a few people said they had had ideas about its cause but couldn't explain how the cause they had thought of could have produced the effect. Actions taken before the problem was solved had been based on experience, on similar problems in the past, on standard operating procedures, and on hunches. The faulty gasket had even been replaced with an identical (and therefore equally useless) one "just to be on the safe side."

Sometimes we stumble onto the cause of a problem. Sometimes we take an action that just happens to correct the effect, although the cause is never explained fully. In the latter case—cause is unknown and the action that solved the problem is one of many taken at the same time—a recurrence of the effect will mean that all those same actions may have to be repeated to ensure correction!

At other times the cause is neither discovered nor stumbled upon, and *no* action corrects the effect. An interim, or holding, action must be devised so that the operation can live with the problem until its true cause is found—or until problem-solving roulette produces a winning number. That happy accident occurs less often than managers would like. Interim action gradually becomes standard operating procedure.

The Case of the Leaking Soybean Oil Filter was reconstructed as a Problem Analysis for plant employees who were learning to use the techniques. It made the point very well that the roulette approach, however familiar, produces frustration and misunderstanding more often than results. Motivation to use a systematic approach grew as soon as the employees recognized that they had worked for several days on a mess that could have been corrected permanently in a matter of hours.

The remainder of this chapter is a step-by-step demonstration of Problem Analysis, exactly as it could have been used when the leaking oil filter problem was first observed.

STATE THE PROBLEM

Before we can describe, analyze, and explain a problem, we must define it. We do this with the *problem statement*, or the name of the problem. It is important to name the problem precisely because all the work to follow—all the description, analysis, and explanation we will undertake—will be directed at correcting the problem *as it has been named*. The name of this problem is "Number One Filter Leaking Oil."

This seems obvious enough. But suppose we had worded the problem statement "Oil on the Filter House Floor." Any way you look at it, oil on the floor is certainly a deviation from SHOULD. Yet it is of known cause, and all that a logical analysis can produce as an explanation is "Number One Filter Leaking Oil." This is where we want to begin our search, not end it.

However simple or complex a problem may seem at the outset, it is always worth a minute or two to ask, "Can the effect of this problem *as we have described it* in the problem statement be explained now?" If it can, as in "Oil on the Floor," we must back up to the point at which we can no longer explain the problem statement.

Vague or generalized problem statements that begin with such phrases as "Low productivity on . . ." or "Sub-standard performance by . . ." must be reworded into specific problem statements that name one object, or kind of object, and one malfunction, or kind of malfunction, for which we wish to discover and explain cause. We must describe exactly what we see, feel, hear, smell, or taste that tells us there is a deviation.

It is tempting to combine two or more deviations in a single problem-solving effort or to try to bunch a bevy of seemingly related problems into one overall problem. Nearly everyone has attended meetings during which two or more distinct problems were tied ankle to ankle in a kind of problem-solving sack race. This procedure is almost always inefficient and unproductive.

SPECIFY THE PROBLEM

Once we have a precise problem statement, the next step in Problem Analysis is to describe the problem in detail or to specify it in its four dimensions:

WHAT– the identity of the deviation we are trying to explain

WHERE– the location of the deviation

WHEN– the timing of the deviation

EXTENT– the magnitude of the deviation

FIGURE 3

SPECIFY THE *IS*

	SPECIFYING QUESTIONS	*IS—PERFORMANCE DEVIATION*
WHAT	WHAT specific object has the deviation?	Number 1 Filter
	WHAT is the specific deviation?	Leaking oil
WHERE	WHERE is the object when the deviation is observed (geographically)?	At the northeast corner of the filter house
	WHERE is the deviation on the object?	At the cleanout hatch
WHEN	WHEN was the deviation observed first (in clock and calendar time)?	3 days ago, at the start of the shift
	WHEN since that time has the deviation been observed? Any pattern?	Continuously, on all shifts
	WHEN, in the object's history or life cycle, was the deviation first observed?	As soon as oil goes into the filter, at the start of the shift
EXTENT	HOW MANY objects have the deviation?	Number 1 Filter only
	WHAT is the size of a single deviation?	5-10 gallons of oil leaked per shift
	HOW MANY deviations are on each object?	N/A
	WHAT is the trend? (…in the object?) (…in the number of occurrences of the deviation?) (…in the size of the deviation?)	Stable—leaks daily, about the same amount

Information on the effects of any deviation will fall within one of these four dimensions. Within each we ask *specifying questions* that will flesh out our description of how the deviation presents itself to our senses. The answers to the questions will give us exactly the kinds of information that will be most useful for the analysis. See Figure 3.

In the dimension of EXTENT, the response to "How many deviations are on each object?" is N/A—not applicable. This illustrates the fact that every problem is unique, and its context reflects that uniqueness. As a result, one or more of the specifying questions may not produce useful information. Nevertheless, we ask. We always attempt to answer every question. Skipping questions that probably don't matter destroys the objectivity we are working so diligently to maintain.

Given only a few variations in wording, any problem can be described by answering the specifying questions—whether the problem concerns a unit, a system, part or all of a function, or human performance. Our choice of wording should indicate that our five senses have detected a problem. When we are dealing with a human performance problem, however, we must alter the questions to reflect the fact that we are observing people and behavior, not units and malfunctions. There are other variations on the basic techniques. When we are working with human performance, we usually need to use a combination of Rational Process ideas—not only those found within the Problem Analysis process. For these reasons, human performance is dealt with separately in Chapter Eight, after all the Rational Processes have been explained.

Once we have described our problem in the four dimensions of WHAT, WHERE, WHEN, and EXTENT, we have the first half of the total specification we want. It is the second half that will render it a useful tool for analysis.

IS and IS NOT: A Basis of Comparison

We know that our problem IS "Number One Filter Leaking Oil." What would we gain by identifying a unit that COULD BE leaking but IS NOT? Or the locations at which oil COULD BE observed to leak but IS NOT? Such data would give us what we need to conduct an analysis: *a basis of comparison*. Once we have identified COULD BE but IS NOT data, we will also be able to identify the peculiar factors that isolate our problem: exactly what it is, where it is observed, when it is observed, and its extent or magnitude. These peculiar factors will lead us closer to the problem's cause.

Suppose for a moment that you have two identical potted plants growing in your office. One thrives but the other does not. If you take the wilting plant out of the office and ask someone about the probable cause for its sorry appearance, you will get any number of educated guesses. But if the same person observes that the two plants have not been receiving identical treatment (the thriving plant is on a sunny window sill; the wilting one, in a dim corner), speculation as to the cause will be immediate and more accurate than it could have been without a basis of comparison. *Regardless of the content of a problem, nothing is more conducive to sound analysis than some relevant basis of comparison*.

In Problem Analysis, we conduct the search for bases of comparison in all four dimensions of the specification. We will now repeat our problem statement and the specifying questions and answers, and add a third column called Closest Logical Comparison. In this column, we will establish the problem as it COULD BE but IS NOT in terms of WHAT, WHERE, WHEN, and EXTENT. The closer the comparison, the more tightly the dimensions of the problem will be defined. Let us see how this works out in Figure 4.

Note that the second specifying question in the WHAT dimension does not suggest a close, logical comparison. In this case, leaking oil cannot be compared usefully with any other specific malfunction with the hatch. The decision as to what is close and what is logical must rest with the judgment of the problem solver or the team. In many cases, it is extremely important to identify the malfunction that COULD BE but IS NOT in order to narrow the scope of the search for cause. Each Problem Analysis is unique to the content of each problem.

Once we have identified bases of comparison in all four dimensions, we are able to isolate key distinguishing features of the problem. This approach is similar to describing the outlines of a shadow. With the completion of the IS NOT data in our specification, the outlines begin to suggest the components capable of having cast the shadow.

FIGURE 4 **SPECIFY THE PROBLEM**

PROBLEM STATEMENT: Number One Filter Leaking Oil

	SPECIFYING QUESTIONS	*IS—PERFORMANCE DEVIATION*	*IS NOT—CLOSEST LOGICAL COMPARISON*
WHAT	WHAT specific object has the deviation?	IS Number 1 Filter	COULD BE but IS NOT Numbers 2-5
	WHAT is the specific deviation?	IS leaking oil	(No logical comparison)
WHERE	WHERE is the object when the deviation is observed (geographically)?	IS observed at the northeast corner of the filter house	COULD BE but IS NOT observed at other filter locations
	WHERE is the deviation on the object?	IS observed at the cleanout hatch	COULD BE but IS NOT observed at other filter locations, at cleanout hatches of Numbers 2-5
WHEN	WHEN was the deviation observed first (in clock and and calendar time)?	IS first observed 3 days ago, at the start of the shift	COULD BE but IS NOT observed before 3 days ago
	WHEN since that time has the deviation been observed? Any pattern?	IS observed continuously, on all shifts	COULD BE but IS NOT observed when the unit is not in use
	WHEN, in the object's history or life cycle, was the deviation first observed?	IS first observed as soon as oil goes into the filter, at the start of the shift	COULD BE but IS NOT observed at a time later on in the shift
EXTENT	HOW MANY objects have the deviation?	IS Number 1 Filter only	COULD BE but IS NOT Numbers 2-5
	WHAT is the size of a single deviation?	IS 5-10 gallons of oil leaked per shift	COULD BE but IS NOT less than 5 or more than 10 gallons per shift
	HOW MANY deviations are on each object?	N/A	N/A
	WHAT is the trend? (…in the object?) (…in the number of occurrences of the deviation?) (…in the size of the deviation?)	Stable—leaks daily, about the same amount	COULD BE but IS NOT increasing or decreasing in frequency or in size

DEVELOP POSSIBLE CAUSES FROM KNOWLEDGE AND EXPERIENCE OR DISTINCTIONS AND CHANGES

Knowledge and Experience

We usually have ideas about the possible causes of a problem, but, given the benefit of the IS/IS NOT comparison, some new ideas may come to mind while others may seem less plausible. Experts and those close to the problem may have ideas about possible causes but will still find the information in the specification useful. Brainstorming is an effective technique to use to quickly list many ideas without evaluating or discussing them. The purpose is to cast a large net in search for the true cause.

In all cases, a short statement that describes how the cause works is needed. Simply pointing to the gasket as the cause will not help us confirm or eliminate it as a cause. What about the gasket creates the leak? Is it too large, too small, too hard, or too soft? Saying that uneven surfaces of gaskets allow leakage suggests a different cause and, perhaps, a different fix than saying that the square corners cause the gasket to seal incorrectly.

If this search yields only implausible causes, or produces far more causes than can reasonably be evaluated in the time available, then consider distinctions and changes.

Distinctions

Number One Filter leaks; Numbers Two through Five might, but they do not. What is *distinctive* about the Number One Filter *compared with the others?* What stands out?

As the question "What is distinctive about…?" is applied to all four dimensions of a problem, our analysis begins to reveal important clues to the cause of the problem—*clues*, not answers or explanations. Let us return for a moment to the wilted potted plant in a dim corner of the office. With a basis of comparison (the identical plant that thrives on a sunny window sill), we quickly see a factor that is highly suggestive of cause. We said earlier that anyone observing this difference in treatment is likely to offer a quick opinion about the plant's wilted appearance. This natural cause-and-effect thinking pattern that we all employ ensures that we all use this kind of reasoning when confronted with a problem *provided that we observe a distinction that taps something in our experience.*

At this point in Problem Analysis, we identify the distinctions that characterize the problem in terms of WHAT, WHERE, WHEN, and EXTENT when compared with the WHAT, WHERE, WHEN, and EXTENT that *might* characterize it but do not. We will now repeat all the columns we have already developed and add a column headed What Is Distinctive About…. This is shown in Figure 5. The question we ask to elicit distinctions is this: "What is distinctive about (the IS data) when compared with (the IS NOT data)?"

The four dimensions of a specification yield distinctions of differing quantity and quality. One or more dimensions frequently yield no distinctions at all. Obviously, the goal is quality: new information that is not already in the specification and that is *truly a distinction* for only the IS.

Changes

In Figure 1, the arrowhead indicates change at a point between past acceptable performance—at which time the SHOULD was being achieved—and current unacceptable ACTUAL performance.

Managers who may never have heard of Problem Analysis know that a decline in a formerly acceptable performance suggests that something has changed; common sense tells them to look for that change. But such a search can be extremely frustrating when the manager is faced with an array of changes—changes that are known and planned, changes that are unforeseen or unknown, which continually creep into every operation.

Instead of searching through this mass of changes to find that one, elusive, problem-creating change, we examine the one, small, clearly defined area in which we can be sure of finding it: distinctions in the IS data when compared with the COULD BE but IS NOT data. This is the next step in Problem Analysis.

FIGURE 5

USE DISTINCTIONS

PROBLEM STATEMENT: Number One Filter Leaking Oil

	SPECIFYING QUESTIONS	*IS—PERFORMANCE DEVIATION*
WHAT	WHAT specific object has the deviation?	IS Number 1 Filter
	WHAT is the specific deviation?	IS leaking oil
WHERE	WHERE is the object when the deviation is observed (geographically)?	IS observed at the northeast corner of the filter house
	WHERE is the deviation on the object?	IS observed at the cleanout hatch
WHEN	WHEN was the deviation observed first (in clock and calendar time)?	IS first observed 3 days ago, at the start of the shift
	WHEN since that time has the deviation been observed? Any pattern?	IS observed continuously, on all shifts
	WHEN, in the object's history or life cycle, was the deviation first observed?	IS first observed as soon as oil goes into the filter, at the start of the shift
EXTENT	HOW MANY objects have the deviation?	IS Number 1 Filter only
	WHAT is the size of a single deviation?	IS 5-10 gallons of oil leaked per shift
	HOW MANY deviations are on each object?	N/A
	WHAT is the trend? (…in the object?) (…in the number of occurrences of the deviation?) (…in the size of the deviation?)	Stable—leaks daily, about the same amount

IS NOT—CLOSEST LOGICAL COMPARISON	*WHAT IS DISTINCTIVE ABOUT…*
COULD BE but IS NOT Numbers 2-5 Numbers 2-5?	The Number 1 Filter, when compared with *The Number 1 Filter has a square-cornered gasket; the other 4 have rounded gaskets.*
(No logical comparison)	
COULD BE but IS NOT observed at other filter locations	The northeast corner of the filter house when compared with other filter locations? *This location is nearest to the feedwater pump, exposing the Number 1 Filter to higher vibration levels than the other 4 filters.*
COULD BE but IS NOT observed at the cleanout hatches of Numbers 2-5	The cleanout hatch when compared with other cleanout hatches? *(No information not already noted above.)*
COULD BE but IS NOT observed before 3 days ago	3 days ago, at the start of the shift, when compared with the period of time before that? *There was a monthly maintenance check just prior to the start of the shift 3 days ago.*
COULD BE but IS NOT observed when the unit is not in use	Continuous leaking, on all shifts, when compared with not leaking when the unit is not in use? *Oil flows through the unit under pressure only when the filter is in use.*
COULD BE but IS NOT observed at a time later on in the shift	The start of any shift when compared with any time later on during the shift? *It's the first time oil comes into the filter under pressure. The cleanout hatch is opened and refastened daily at every shift.*
COULD BE but IS NOT Numbers 2-5	(No information not already noted above.)
COULD BE but IS NOT less than 5 or more than 10 gallons per shift	5-10 gallons of oil leaked per shift when compared with less than 5 or more than 10?
N/A	N/A
COULD BE but IS NOT increasing or decreasing in frequency or in size	N/A

What changes are most likely to suggest the cause of our problem? Those that are most relevant to its peculiar features of WHAT, WHERE, WHEN, and EXTENT. Suppose there had been eight operational and/or maintenance changes in the filter house over the past six months. Even if we knew the exact number and kind of changes that had occurred, which ones would we want to examine first? Six changes that affected all five filters? Or two that affected only the Number One Filter? Or seven that affected operations during the past six months? Or one that was instituted only a day or a week before the problem was first observed?

When we ask the following question of each distinction, "What changed in, on, around, or about this distinction?", we are going straight for the changes capable of suggesting cause. We are bypassing any changes that *may have occurred but are not relevant* to the key features of this problem. The relationship of distinctions and changes and the relationship of both to the generation of possible causes are very important.

Suppose that, when the problem was first recognized, a problem analyst had been presented with the distinction of the square-cornered gasket on the leaking filter. He or she might not have grasped its significance. Why not? Because unimportant distinctions abound between one thing and another and between one period of time and another. Compare any two pieces of equipment that have been in place for a few years and you will usually find a number of distinctive features about each. Parts have broken and been repaired. New, perhaps slightly different, parts have replaced worn-out ones. Operating procedures may vary slightly from one to the other for any of a dozen reasons.

The leaking filter might have had a different type of gasket for five years yet never have leaked until recently. *But when this distinction is appreciated as representing a change*—and a change that occurred the evening before the leaking was observed—*its significance as a clue is greatly heightened.*

To the distinctions of the IS data as compared with the IS NOT data, we now add the change question and the answers to it. This is shown in Figure 6.

FIGURE 6

USE CHANGES

PROBLEM STATEMENT: Number One Filter Leaking Oil

ABOUT…	*WHAT IS DISTINCTIVE ABOUT THIS DISTINCTION?*	*WHAT CHANGED IN, ON, AROUND, OR*
WHAT	The Number 1 Filter, when compared with Numbers 2-5? *The Number 1 Filter has a square-cornered gasket; the other 4 have rounded gaskets.*	The square-cornered gasket is a new type, installed for the first time 3 days ago at the monthly maintenance check.
WHERE	The northeast corner of the filter house when compared with other filter locations? *This location is nearest to the feedwater pump, exposing the Number 1 Filter to higher vibration levels than the other 4 filters.*	Nothing. Location and vibration levels have been the same for years.
	The cleanout hatch when compared with other cleanout hatches? *(No information not already noted above.)*	
WHEN	3 days ago, at the start of the shift, when compared with the period of time before that? *There was a monthly maintenance check just prior to the start of the shift 3 days ago.*	A new type of square-cornered gasket was installed for the first time 3 days ago, as noted above.
	Continuous leaking, on all shifts, when compared with not leaking when the unit is not in use? *Oil flows through the unit under pressure only when the filter is in use.*	Nothing.
	The start of any shift when compared with any time later on during the shift? *It's the first time oil comes into the filter under pressure. The cleanout hatch is opened and refastened daily at every shift.*	Nothing. Nothing. The filter has been cleaned, hatch refastened on every shift for years.
EXTENT	(No information not already noted above.)	N/A
	5-10 gallons of oil leaked per shift when compared with less than 5 or more than 10?	Nothing.
	N/A	N/A
	N/A	N/A

Somewhere in the distinctions and changes that emerge during Problem Analysis lies the explanation of cause—provided that all relevant information about the problem has been obtained and included. Several possible causes will sometimes emerge. In some cases, pieces of information must be knitted together to provide a satisfactory explanation of the problem's cause. Two changes operating in combination may produce a performance deviation that one of those changes alone cannot.

We identify possible causes by asking the following question of each item in the categories of distinctions and changes: "How could this distinction (or this change) have produced the deviation described in the problem statement?" Again, as with using knowledge and experience, it is necessary to develop statements that explain how the cause creates the deviation. Beginning at the top of Figure 6—distinctions and changes relative to WHAT—we immediately notice the combination of a distinction and a change:

> **Possible Cause:** The square-cornered gasket (a distinction between the Number One Filter and the other four) from the new supplier (a change represented in that distinction) is too thin and unevenly constructed. This caused the Number One Filter to leak oil.

Other possible causes can be generated from the distinctions and changes in our analysis. Knowing the true cause, they will not appear to be strong contenders, but they are possible. We will describe them in order to help explain the testing step of Problem Analysis in the following section.

One possible cause can be derived from the WHERE dimension. It was noted that the northeast corner of the filter house, where the Number One Filter stands, contains the feedwater pump. This distinction has some significance: The leaking filter is exposed to considerably greater vibration than the other four filters. This represents no change. It has always been that way. We know from the specification, moreover, that the current leakage is occurring at the cleanout hatch, not at the valves. When vibration caused leakage in the past, it occurred at the valves. Nevertheless, at this point in Problem Analysis, we should generate all reasonable possible causes, without focusing only on the problem's true cause. Vibration is given the benefit of the doubt.

> **Possible Cause:** Vibration from the feedwater pump in the northeast corner of the filter house (distinction in the dimension of WHERE) causes the Number One Filter to leak oil.

TEST POSSIBLE CAUSES AGAINST THE SPECIFICATION

The last statement is listed as a possible cause simply because it is possible. That's important. By including *all* possible causes, we lose nothing, maintain our objectivity, and reduce the incidence of conflict and disagreement in the explanation of a problem. In the testing step of Problem Analysis, we let the facts in the specification perform the function of judging the relative likelihood of possible causes.

We ask of each possible cause, "*If* this is the true cause of the problem, then how does it explain each dimension in the specification?" The true cause must explain each and every aspect of the deviation, since the true cause created the *exact* effect we have specified. Effects are specific, not general. Testing for cause is a process of matching the details of a postulated cause with the details of an observed effect to see whether that cause could have produced that effect. For example:

> **If** vibration from the feedwater pump is the true cause of the Number One Filter leaking oil, **then** how does it explain **why**:
>
> WHERE: Leaking IS observed at the cleanout hatch; IS NOT observed at the cleanout hatches of Numbers Two through Five.
>
> WHEN: Leaking IS observed three days ago; IS NOT observed before three days ago.

Vibration previously affected the valves and *not* the cleanout hatch. It doesn't make sense to say that vibration causes a cleanout hatch to leak. Why would vibration cause leaking to begin three days ago and not before? Unless we are willing to make some rather broad assumptions, we cannot make this possible cause fit the observed effects. Our judgment tells us that this is an improbable explanation at best.

Another possible cause is suggested by the distinctions and changes found in our analysis:

Possible Cause: New maintenance people (a distinction that also represents a change in the WHEN dimension) are not using a torque wrench to close the cleanout hatch. This is causing the Number One Filter to leak.

Testing this possible cause with our "If. . .then. . ." question, we quickly find ourselves at a loss to explain why the leaking occurs only on the Number One filter and not on the other four. After all, the same people are responsible for maintaining all five filters. If they failed to use a torque wrench on the Number One Filter, why would they do so on all the others? We would have to make broad assumptions to make the cause fit the observed effects: "Well, they probably use the torque wrench on the other four. But back in the northeast corner of the filter house, where it's so dark and there's all that vibration from the feedwater pump, they choose to forget it and don't tighten the cleanout hatch the way they should." This explanation is more improbable than the other one.

The actual cause fits all the details of the effect as specified: a new, thinner, square-cornered gasket that was put on the Number One Filter three days ago during the monthly maintenance check. It explains the WHAT, WERE, WHEN, and EXTENT information. It requires no assumptions at all to make it work. It fits as hand does to glove, as cause and effect *must* fit. There is less likelihood of the other possible causes being true.

DETERMINE THE MOST PROBABLE CAUSE

By now in our analysis, we will have identified *the most likely possible cause* that explains the deviation better than any of the other possible causes. But this most likely possible cause seldom proves to be, beyond the shadow of a doubt, the true cause. Of course this is not always the case. Often, several possible causes, including the true cause, carry assumptions that must be true if the cause is to be true. We compare assumptions by asking "Which cause has the fewest assumptions? Which cause has the most reasonable assumptions? Which cause has the simplest assumptions?" Our selection of the most probable cause may depend as much on the quality of the assumptions as on the quantity. Sometimes judgment is needed to select the most probable cause. To improve our chances of success, however, we need to spend time and effort in confirming the cause.

VERIFY ASSUMPTIONS, OBSERVE, EXPERIMENT, OR TRY A FIX AND MONITOR

Confirmation is an independent step taken to prove a cause-and-effect relationship. It depends on bringing in *additional information* and taking *additional actions*.

To *confirm* a likely cause is to *prove* that it did produce the observed effect. In our example all we need to do is simply look at the gasket in operation and see whether it leaks (observe). Or, we can trade the gasket from the Number One Filter for the non-leaking gasket from one of the other filters (experiment). Or, we can obtain a gasket with rounded corners from the old supplier, install it, and see whether the leaking stops (try a fix and monitor). Any of these would prove that the leaking resulted from the installation of a new, thinner, square-cornered gasket bought at a bargain price.

Sometimes no *direct confirmation* is possible and we must rely on our assumptions. A rocket booster explodes in flight. Most of the tangible evidence is destroyed. We would certainly not want a second such accident. All that can be done is to verify assumptions generated during the testing against the specification. "If *this* happened, then *that* would make sense…." Devise ways to verify the assumptions. The assumptions must be true in order for the cause to be true.

Confirmation is possible in most problem situations. What it consists of will depend on the circumstances. We want to use the safest, surest, cheapest, easiest, quickest method. A mechanical problem may be duplicated by consciously introducing a distinction or a change that seems highly indicative of cause. Many problems are confirmed by "putting on the old gasket"—that is, reversing a change to see whether the problem stops (try a fix and monitor). In that case, confirmation provides corrective action. Resolution coincides with the last step in the process of Problem Analysis.

Failure

Of course, we may fail. While the most common cause of failure is too little data in the specification, there are three other major reasons for failing to solve a problem despite using Problem Analysis:

- ➢ Using inaccurate or vague information to describe the problem.
- ➢ Insufficiently identifying key distinctions and changes related to the IS data in the specification.
- ➢ Allowing assumptions to distort judgment during the testing step. The greater the number of assumptions we tack onto a possible cause in order to label it "most probable," the less chance there is that it will survive confirmation. There is nothing wrong with making assumptions as long as we regard them as such and do not prematurely grant them the status of fact.

A Process, Not a Panacea

Thousands of people have used these techniques to solve problems that seemed otherwise unsolvable or solvable only by far greater expenditure of time and money. On the other hand, many of these same people have failed to solve other problems they were sure they could crack—"if only they had stayed with the process." Problem Analysis enables us to do a good job of gathering and evaluating information about problems. However, there are limitations to the power of the process to produce the right answers. If we cannot track down the key facts needed to crack a problem, that problem will continue to defy solution. No approach or process, however systematically or meticulously applied, will unlock its secret.

Chapter Summary

The shadows cast by our problems may be perplexing. Yet the *structure* of *all* problems is always the same. It is knowledge of this structure that enables us to move systematically from definition to description to evaluation to hypothesis to confirmation of cause.

➢ The **Problem Statement** is a concise description of both the object of our concern and the deviation or malfunction for which we want to find the cause. In our example, that statement was "Number One Filter Leaking Oil."

➢ The **Specification** of the problem is a comprehensive description of the problem's WHAT, WHERE, WHEN, and EXTENT—as it IS and as it COULD BE but IS NOT. The Number One Filter IS leaking; each of the other four COULD BE but IS NOT. The location of the leak IS the cleanout hatch; the leak COULD BE but IS NOT observed at the cleanout hatches of Numbers Two through Five. From the identification of this IS… COULD BE but IS NOT data, we assemble bases of comparison that will lead us to an understanding and resolution of the problem.

➢ Our own **Knowledge** and **Experience**, or that of experts, may suggest possible causes. Using the specification as a guide, we look to generate as many possible causes as we reasonably can. We then test these against the specification.

➢ If we have too many or too few causes to consider, or if all of the causes we generate fail to test against the specification, we look for **Distinctions**—features in all four dimensions that characterize only the IS data. We ask, "What is distinctive about the Number One Filter when compared with Filters Two through Five?" We carry this kind of questioning through the other three dimensions. The result is a collection of key features that characterize the WHAT, WHERE, WHEN, and EXTENT of our problem.

➢ We then study each distinction to determine whether it also represents a **Change**. It is at this point in our analysis that we recognize the square-cornered gasket on the leaking filter—not only as a distinctive feature of that filter but also as a change. Until the day before the problem appeared, the Number One Filter had been equipped with the same type of round-cornered gasket used on the other units.

➢ When all the distinctions and changes have been identified, we begin to **Identify Possible Causes**. Each distinction and change is examined for clues to cause. Each resultant hypothesis of cause is stated to illustrate not only what caused the problem but how it did so: "The square-cornered gasket from the new supplier is too thin and unevenly constructed. This caused the Number One Filter to leak."

➢ Each possible cause we generate is then **Tested** against the specification. It must explain both the IS and IS NOT data in each dimension. To graduate to the status of **Most Probable Cause**, it must explain or withstand all the facts in the specification. Unless we make some farfetched assumptions, "greater vibration in the northeast corner of the filter house," for example, cannot explain either the leak at the location on the filter or the time period that characterized this problem. Vibration, as a possible cause, is less likely to have produced the problem than the installation of the new gasket.

➢ The final step in Problem Analysis is **Confirmation** of the true cause. We are hoping to demonstrate, as closely as possible, the cause-and-effect relationship. The confirmation is carried out in the work environment if possible. In our example, this can be done either by duplicating the effect suggested by the cause or by reversing the change suspected of having caused the problem to see if the problem stops.

If no possible cause that has been generated passes the testing step, or if no cause that does pass it survives the confirmation step, the only recourse is to tighten up the prior work. We may need more detailed information in the specification, in the ensuing identification of distinctions of the IS data, and in the identification of changes in and around the distinctions. This may lead to new insights, to the generation of new possible causes, and, finally, to a successful resolution.

If we fail to find the true cause of a problem through these techniques, it is because we failed to gather and use information appropriately. We cannot use information that we do not have. If we get the information but use it carelessly, the result may be no better.

The logic of Problem Analysis defends conclusions that support facts; it sets aside those that cannot. It is a process that makes use of every bit of experience and judgment we possess; it helps us to use both in the most systematic and objective way possible.

Problem Analysis enables people to work together as a team, pooling their information in a common format, to determine the cause of a problem. Most deviations are so complex that one person alone does not have the information necessary to find, test, and confirm the cause. When all those who hold important data have a mechanism for integrating it, they can begin to find the unknown cause. Otherwise, that discovery may be stalled by misunderstandings and other barriers to communication.