# Value Managed Failure Analysis and Product/Process Improvement

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## ABSTRACT:

This paper describes how to tailor the Value Engineering/Value Management methodology's job plan to be used as a failure analysis and product/process improvement tool. The emphasis is placed on the function analysis of the product, process, or service. The FAST model is used as an aid to target functions that have experienced some type of failure, or need improvment. Then, identifying potential problems and most likely causes of failure of these functions facilitates the generation of superior ideas on how to fix the failure, or make improvements.

## INTRODUCTION

Try to imagine yourself at 8:00 AM on the first day of a value engineering workshop you've been planning for the past six weeks. You are a relatively new value engineer, still somewhat unsure of yourself. You're hoping that you and your team can measure up to the General Manager's expectations for cost reduction on the product you have been assigned to study. Afterall, over 50% of the division's total automatic flight control business depends on this one very large aerospace and commercial aircraft company. In order to maintain their favored vendor status, you must find a way to cut your division's costs on its flight control products by 25%, or you might loose this very important customer.

Now its 8:05 AM and you have just introduced the topic of VE study as the Director of Quality comes into the room and asks you for his attention. He tells you and your team that a very serious situation has just developed. He explains that the last lot of elevator feel computers for the Boeing 737/757 aircraft the company manufactures have developed serious problems during final test. This sophisticated electro-hydraulic control module produces a variable hydraulic pressure used to produce resistance, or artificial "feel" in the pitch axis control system which the pilot commands or "steers" the pitch of the aircraft with. Without this very important component, the pilot could not tell how much pitch he was applying to the aircraft and he would be unable to control it.

The problem, the quality director explains, is a serious oscillation in the computer valve. Production has been shut down on the line. Additionally, the division is scheduled to have a quality audit by Boeing any day now. The division's favored vendor status is seriously jeopardized because the 98% quality rating, and perfect on-time delivery status is threatened. It would not look very good at all to be experiencing this problem during the quality audit! Not to mention this is a very expensive problem to fix since the feel computers are fully assembled by the time they reach final test. Fixing the problem requires totally disassembling the feel computer and replacing the offending valve just to find the next valve might be defective.

The Quality Director further explains management is assembled up stairs in the executive conference room to try to resolve the problem, but, they're getting nowhere. He explains that he feels you have the right team assembled to solve this problem since you have representatives from engineering, production, quality, procurement, test, and manufacturing engineering on the team. All you need to do is change your focus from cost reduction, to fixing this problem.

Suddenly, in less than 10 minutes the total charter for your value engineering workshop has changed. There is no doubt about it, you **must** find a solution to this problem. What do you do?

This was an actual situation I encountered early in my career as a value engineer at E-Systems Inc., Montek Division in Salt Lake City, Utah. I learned a very valuable lesson from this experience. I learned that because Value Engineering (or Value Management) is a structured, function oriented, multi-disciplined approach to problem solving, it is a very powerful tool for not only cost reduction, but, analyzing and developing potential solutions for system failures. Additionally, I have learned that in looking at a system's potential failures and their most likely causes facilitates the generation of more ideas for improvement of that system than may be experienced otherwise. I have used this modified VE approach throughout my career and have found it to be most useful in resolving system failures and improving system reliability. It is also very useful in identifying process improvements.

## METHODOLOGY

Value Managed Failure Analysis results in significant improvements to quality and reliability by focusing the teams attention on the most likely functions that could fail, and their most likely causes of failure. Then, the team develops ways to avoid these potential causes of failure, or ways to fix the failures that have occurred and means to prevent their reoccurrence. It capitalizes on the structured VE job plan to first clearly define the problem in the information phase, and identify the system's basic function(s) and the critical functions required to support the basic function. You may recall that the definition of a basic function is "the principle reason for the existence of a 'thing'.[1]" Or, another definition is "that function which makes a product, process, or service 'work or sell'." Therefore, if a product, or system has failed, then its basic function has failed. This is where Value Management can be a valuable methodology for solving such problems. This methodology also capitalizes on the very nature of Value Management as it is an "intense inter-disciplinary problem solving activity."

There are a few minor modifications to the job plan that occur primarily in the Information Phase. These modifications are structured toward determining the root-cause of the failure by isolating the functions that have contributed to the failure, and identifying potential problems that could lead to the failure in these functions. Then, most likely causes of failure are developed that explain how the potential problems could occur. This adds an additional level of brainstorming and evaluation to the job plan in the information phase geared toward identifying the most likely causes, and root-cause(s) of failure.

## SOLVING THE PROBLEM

In the example of the Boeing 737/757 computer valve failure, the value management team quickly isolated the problem by focusing on the basic function of the valve which was "control pressure." Answering the question, "How does the computer valve 'control pressure'" led to more functions. These functions were then ranked by their level of importance as to how they might be contributing to the failure which was exhibited as oscillation in the valve. Subsequent brainstorming and ranking of the answers as to the **most likely cause** of this failure narrowed the problem down to a small orifice produced by electrical discharge machining (EDM) through the wall of the valve. This hole was responsible for allowing hydraulic fluid to flow from one side of the valve to the other upon a signal from the computer, resulting in a change in direction of the valve stem. The edge of this hole, called the "metering edge" was .0002 in. thick and needed to be very smooth to accommodate a laminar flow through the orifice. Otherwise, the hydraulic fluid would experience cavitation as it flowed over the metering edge of the orifice resulting in the telltale oscillation that had been experienced in the final test of the feel computer.

Once the problem had been isolated to this jagged metering edge, which by-the-way could not be seen with the current inspection equipment, brainstorming could begin on why this problem existed and how it could be prevented from happening again. **The most likely cause of why the metering edge was not smooth was established to be that the EDM wire was breaking through the hole instead of burning a smooth edge.** This would cause a rough metering edge.

From this information, the team brainstormed potential fixes to the problem. This brainstorming occurred in the traditional manner and numerous good ideas surfaced. These ideas were grouped into categories which included design changes, process changes, training and operator aids, and new inspection equipment.

Oh, by-the-way, it took the team only two days to develop a detailed corrective action plan to fix this problem using the Value Managed Failure Analysis methodology. The suggestions were implemented, and the valve oscillation problem was solved. The quality audit went smoothly and the division's favored vendor status with the Boeing Company was preserved. As a result of this and other VM studies, and a great deal of hard work by the whole division in implementing the suggestions, Boeing awarded a 5 year extension to their 5 year Long Term Business Agreement for flight control equipment used on the 737, 747, 757, and 767 aircraft worth between $175 and $200 million over the life of the agreement.

## PROCESS IMPROVEMENT EXAMPLE

The next example is presented to further illustrate how the Value Managed Failure Analysis works in concert with other well known techniques such as Kepner-Tregoe problem analysis for determining the root cause of a problem prior to the VM workshop. Then, using the VM Failure Analysis as a process improvement tool yields superior results.

In this example, 55 gal drums that were used to store nuclear processing waste were found to have pinholes in the upper third of the drum. The waste consisted of anything from discarded rags, gloves, and protective clothing to solvents and chemicals. This waste was further contaminated with low levels of radioactive waste containing transuranic (TRU) elements. Transuranic waste (TRU) refers to radioactive materials contaminated with greater than 100 nanocuries per gram of alpha-emitting radionuclides with half-lives greater than 20 years [2]. There was evidence that some material had leaked through the pinholes, however, this evidence consisted only of streaks of dried material on the outside of the drums, or in some cases, blistered paint.

The waste drums were being prepared for permanent storage at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico in order to meet the terms of an agreement between the Department of Energy and the State of Idaho, commonly known as the "Governor's Agreement." Part of this preparation involved installation of a vented plug to allow hydrogen gas to aspirate from the inside of the drums.

The drums were stored in a Resource Conservation and Recovery Act (RCRA) approved storage facility at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory. As such, the RCRA Part B permit for the facility required that the State of Idaho Department of Environmental Quality be notified if there were any problems, or concerns about the storage of the waste. Therefore, immediate efforts were initiated to determine the cause of the pinholes, how much of the inventory of hazardous waste was involved, and the best course of mitigative action to pursue. Also, it was determined that there was never any danger to the public or workers.

The resolution of this problem occurred in two phases. The first phase required a thorough root-cause analysis of the problem. A multi-disciplined team was assembled and the Kepner-Tregoe (K-T) problem analysis technique [3] was used in this phase to isolate the most probable cause of the pinholes.

The facilitated meeting followed a structured agenda that began with developing a response to three probing questions. The questions and the team's answers to these questions follows:

1. What is the problem we are here to discuss?

   Ans: There are pinholes found in CH-TRU containers (mainly drums) at the RWMC Transuranic Storage Area (TSA) in the Certify & Store (C&S), Air Support Building-II (ASB-II), and Waste Storage Facilities.

2. Why is this a problem?

   Ans a: A pinhole (deterioration caused by corrosion) in a container per RCRA is considered a breached container which must be managed per RCRA.

   Ans b: The hazardous constituents coming out of holes must be managed as hazardous waste because of the "derived rule".

   Also:

   OVER PACKING PER 40 CFR 265.172 CAUSES:

   - Elimination of container from WIPP shippable inventory -- Can't ship to WIPP 83 gal overpacks at present.
   - Increases waste volume by 30%.
   - Requires more storage space.
   - Elimination of this inventory from the Governor's Agreement and the need to replace it to meet these requirements.

3. Why is a solution necessary?

   - Safety - worker, public & environment.
   - Satisfy Governor's agreement.
   - Satisfy WIPP Waste Acceptance Criteria (WAC).
   - Satisfy RCRA.
   - Satisfy Superfund Amendments and Re-authorization Act of 1986 (SARA) Title III.

This resulted in the formulation of a problem statement for the study which was:

***"There are pinholes in TRU metal waste containers at RWMC that exhibit evidence of leaking."***

Next the team performed a K-T problem analysis to further explore the problem in the four dimensions of identity, location, timing, and magnitude[4]. Out of this, potential causes to the problem were developed. These potential causes were compared against the above four dimensions to determine if they could explain these facts and observations. A crucial fact that surfaced was these particular drums held a volatile organic chemical sludge which contained high levels of chlorides. From this, a "Most Probable Cause" was proposed which was to be verified in activities to be carried out the following week.

This detailed analysis formulated a "most probable cause" for the drum degradation that is manifested by blistered paint and/or pinholes in the drum walls with, or without evidence of leakage of liquid. The K-T approach of first identifying the problem, identifying potential causes, formulating a "most probable cause, or causes" and testing the most probable cause(s) for the true cause(s) is the best way to determine the root cause of the problem which, when solved, will lead to a lasting solution to the problem [5]. The "most probable cause" that the team developed from this analysis was:

"***Drum venting may be allowing moisture and/or water vapor to enter into the drums causing internal drum condensation. This in turn reacts with the chlorides in the waste forming hydrochloric acid. This acid vaporizes, or is formed as a vapor, and migrates through the vent hole in the liner to the headspace between the liner and the drum. This hydrochloric acid vapor condenses and collects on the drum wall resulting in corrosion of the metal from the inside-out primarily in the upper one-third of the drum.***[6]"

The identified actions that were necessary to verify that this most probable cause was the true cause of the problem were:

1. Perform a calorimetric tube test for hydrochloric acid through the drum filter or maybe through the filter hole directly.

2. Investigate/correlate drum lots with failed drums.
   - Database search to compare bad drums [for commonalties]
   - Weight [also, contents, pack dates, etc.]
3. Perform intrusive chemical analysis of a representative sample of drums/metal containers.
4. Swipe inside of drum through vent hole to verify poly bags will contain contamination but not vapors. Also check for evidence of hydrochloric acid.
5. Investigate additives used for solidification to determine relevance for problem - which are probably chlorides.
6. Research manufacturing of drums [dates, lots, specs, tests, etc.].

Once these activities proved that the suspected "most probable cause" was the true cause, then another meeting was scheduled to perform the remaining tasks of:

A) Identify short and long term operational impacts.

B) Identify any attendant operational changes that may be appropriate.

C) Identify potential impacts to WIPP certifiability for the waste streams involved.

D) Identify potential mitigative actions.

E) Evaluate the adequacy of current drum examination and inspection processes.

F) Make recommendations as appropriate.

If these activities could not prove that the suspected "most probable cause" is the true cause, then the problem analysis would have been revisited to determine what observations and facts could be eliminated, and what new information had been learned. Then a new, or additional, "most probable cause(s)" would have been established for further verification of a true cause.

Once the "most probable cause" of this problem was verified, the second meeting was convened to establish a path forward for resolving the problem and address tasks A through F above. The format of this meeting was a Value Managed Failure Analysis workshop.

## IDENTIFYING IMPROVEMENTS

The format of this second meeting followed the six step VM job plan used in Value Engineering including a function analysis of the drum examination and inspection process. Value Engineering was the technique chosen to identify ways to improve this process because it is a powerful interdisciplinary problem solving technique that can be used to identify improvements in any product, process, or service.

The VE workshop followed a structured agenda that began with developing a response to three probing questions. The questions and the team's answers to these questions follows:

1. What is the problem we are here to discuss?

   Ans:

   - The unexpected presence of pinholes in containers. Inability to identify pinholes visually.
   - Need to identify all <u>incompatible</u> waste.

   Definition - Incompatible Waste: Waste that will react with the container, or other waste.

2. Why is this a problem?

   Ans:

   - We need to manage containers/waste to meet the RCRA Part B Permit requirements.
   - We need to assure containers meet [DOT] Type A Transportation requirements.
   - [There are] potential negative impacts to the safety of workers, environment, and the facility.

3. Why is a solution necessary?

   Ans:

   - To <u>ensure</u> safety to workers and environment.
   - To identify additional potential degradation of containers.

- To ensure compliance with RCRA Part B Permit.
- To ensure WIPP-WAC is met.
- To meet the Governor's agreement.
- To meet the consent order[7].

Once these questions were answered, a mission statement was developed which was key to the function analysis and FAST Modeling of the problem. This process also included a thorough root cause analysis of the basic function "determine condition".

By brainstorming ideas as to what problems might occur with this function, and the most likely causes of failure, the team developed a prioritized list of most likely causes of failure. This list formed the basis for brainstorming ideas of how to improve the basic function. Over 80 ideas for improvement were identified using this process which fell into categories of both short-term and long-term recommendations.

Figure 1 illustrates the FAST Model the team developed which helped isolate the functions that were contributing to the inadequacies of the inspection process. The shaded functions were those determined by the team contributing to the less than adequate performance of the basic function. Had time permitted, these functions would have also been evaluated to determine their potential causes of failure and what could be done to improve their performance. However, since time was very limited, it was decided that improving the performance of the basic function would be sufficient.

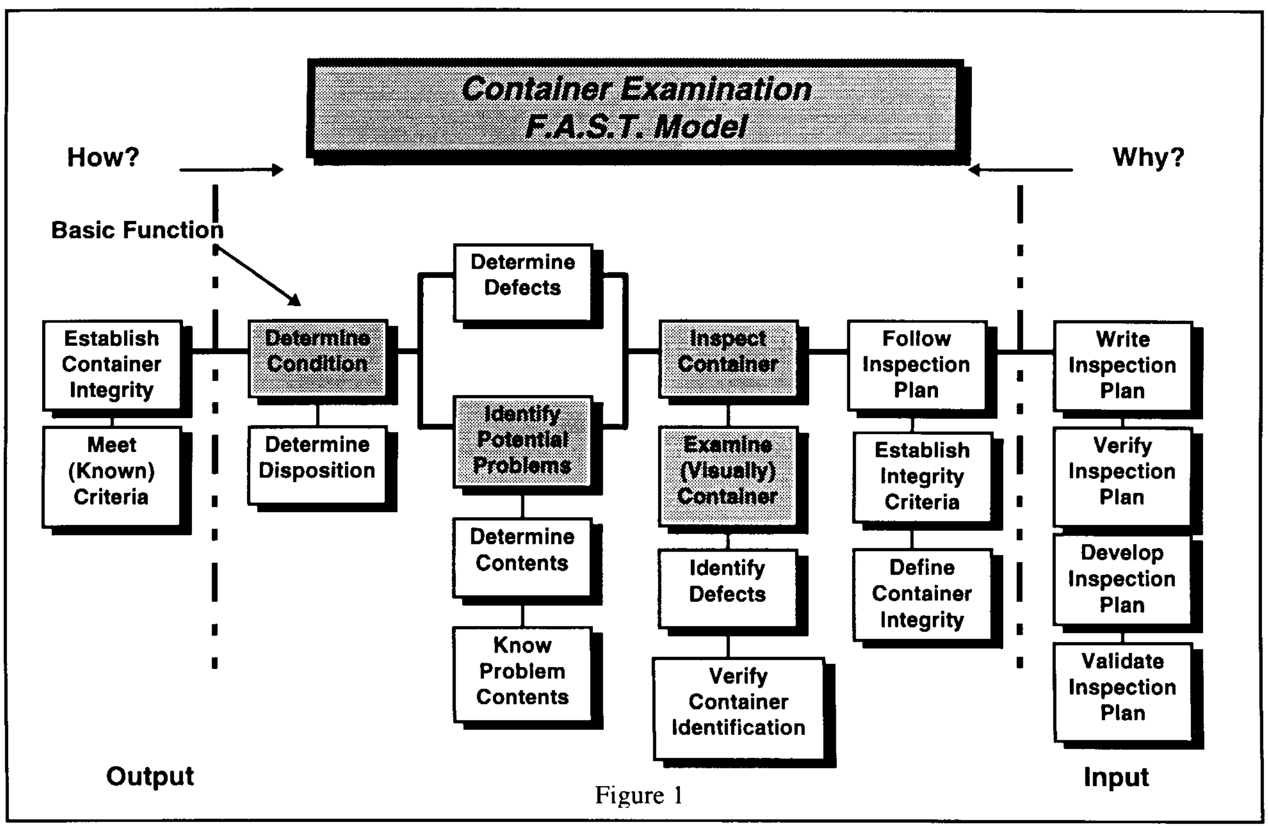


Figure 1

Figure 2 illustrates the brainstorming and scoring of "Potential problems that can occur with '**Determine Condition**'", the basic function.

| Problems that can occur with "Determine Condition" | |
|---|---|
| **Potential Problem** | **Score** |
| ~~Incorrect Container ID~~<br>~~Incorrect Contents~~ | ~~1~~<br>~~5~~ |
| ~~Inaccurate Determination~~ | |
| ~~Deterioration After Inspection/Damage After Inspection~~ | ~~2~~ |
| Inadequate Procedures | 10 |
| Inadequate Equipment | 9 |
| ~~False Positive Reading for Excessive Thinning~~ | |
| Inadequate Training | 10 |
| [Poor] Human Factors [Interface] - Ability to see contents, position container, etc. | 7 |
| ~~Environmental Conditions (Degradation after inspection)~~ | ~~2~~ |
| Management Pressure to Perform | 6 |
| ~~Inadequate Quality Checks~~ | ~~2~~ |
| Inadequate Inspection Criteria | 10+ |
| Subjective Inspection Criteria | 9 |
| Poor Container Condition hampers inspection | 7 |
| Time - Availability - 5 min./drum, 1 min. for inspection | 6 |
| Poor Weather/Environmental Conditions - Human Factors | 8 |
| Work Station Too Cold/Hot (Not Heated/Cooled) | 8 |
| Time of Day | 8 |
| Time of Week | 8 |
| Time of Month (Beginning/End) | 8 |
| Overtime/Schedule (4 - 10s) | 8 |
| ~~Conflicting Requirements~~ | ~~2~~ |
| ~~Poor Inspection Process~~ | ~~8~~ |

Figure 2

Problems scoring higher than 6 were evaluated in the next step of this process. Each potential problem, starting with the 10 category, was then further evaluated by asking the question, "what could cause these problems to occur?" This led to the basis for the most likely causes of failure. In the leaking drum example, some of the most likely causes of failure are shown in figure 3.

**MOST LIKELY CAUSES OF FAILURE**

- **Inadequate Procedures**
  - Results Not Tested/Verified
  - Writer of Procedure is not familiar with process
  - Vague Text
- **Inadequate Training**
  - Trainers have not had direct experience with the inspection process.
  - Inadequate Training Materials:
    - ⇒ Poor Illustrations
    - ⇒ Field Examples Poor
    - ⇒ Materials not definitive enough
  - Little, or no, actual training performed
  - Go/No-Go criteria is not clearly defined to operators.
- **Inadequate Inspection Criteria**
  - Too vague
  - Driven by Management Goals
  - Unclear goals and objectives available for development of criteria.
  - Too little quantitative measures and performance parameters.
  - Condition could not be assessed.
  - No measurement of wall thickness...**etc**.

Figure 3