A Value Management Approach To Improving Quality Performance

SAVE International Conference 2005

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July 2005

Idaho Cleanup Project

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BIOGRAPHY

Jim Wixson has 30 years of experience which includes work in Value Engineering, Systems Engineering, Industrial and Manufacturing Engineering, Project Management, Contracts and Pricing with companies in Utah, Idaho and the INL. He is also an affiliate instructor at the University of Idaho where he teaches courses in Quality Assurance, Management and Organization and New Product Development. Currently an Advisory Engineer in the Project Engineering group for CH2M-WG Idaho, LLC at the Idaho National Laboratory (INL) in Idaho Falls, ID working on the Idaho Cleanup Project. He has been with the INL for 15 years where he has been successful in applying Value Management techniques in both traditional and non-traditional VM settings.

Mr. Wixson graduated from the University of Utah in 1977 with a BS in Industrial Engineering, an MBA from the University of Phoenix (1986), and has a Masters degree in Systems Engineering from the University of Idaho (2003). He also has a Masters Certificate in Project Management from Villanova University (2004). He is an active member of the Society of American Value Engineers (SAVE), Society of Manufacturing Engineers (SME), and the American Society for Quality (ASQ) of which he is currently serving as the Eastern Idaho Section Chairman.

ABSTRACT

In October 2001, the Department of Energy's, Office of Price-Anderson Enforcement determined that the continuous improvement aspect of the INL Quality Assurance Program was inadequate. At the request of the INL Senior Management, a Quality Assurance Operations (QAO) Task Team was identified and requested to review the INL practices to determine whether the INL was performing the activities that are required for Quality Implementation. The team consisted of INL managers from Operations, Quality Assurance, Document and Records Management, Construction Services, Radiological Control, and Engineering. FAST modeling combined with other analytical techniques were used to identify areas for improvement and resolve the issues related to inadequate continuous improvement efforts.[1]

INTRODUCTION

The INL has committed to having a compliant Quality Assurance Program (QAP). However, in October 2001, the DOE's, Office of Price-Anderson Enforcement determined that the continuous improvement aspect of the INL QAP was inadequate.

The INL Senior Management, being aware of the potential consequences, directed that a Task Team be formed to review the INL practices to determine whether the INL activities were performed that help continuously improve the QAP and its implementation. The team consisted of INL managers from Operations, Quality Assurance, Document and Records Management, Construction Services, Radiological Control, Engineering, and Research and Development.

The Task Team identified three specific tasks to complete. The first task was to identify whether the INL problems were the result of the Quality Assurance Program process or Quality Assurance Program implementation. The second task was to identify specific weaknesses that were contributing to the problems identified in the first task. Finally, based on the identified problems, the third task was to identify actions to correct either the Quality Assurance Program process or the Quality Assurance Program implementation.

The Quality Assurance Operations (QAO) team developed a number of possible hypotheses to determine whether the INL had a QA program problem or QA implementation problem. These hypotheses were based on the significant operational experience of the QAO team and a Failure Modes and Effects Analysis (FMEA) of INL QA Implementation. The QAO team performed the FMEA using the Function Analysis Systems Technique (FAST) to form a framework that represented the functions of INL QA Implementation and their relationship to each other. Then, deficiencies collected in a companywide deficiency tracking database were mapped to these QA implementation functions to identify which functions were reflected in the deficiencies and potential failure modes that were causing these functions to have less than adequate performance. The QAO team concluded from these analyses that the process problems were a function of how the QA process was implemented, rather than the QA process itself.

ANALYSIS METHODOLOGY

The basic method used to evaluate the INL QA program performance was designed first to maximize the identification of possible problem areas through divergent analyses, then, once all of the possible problem areas had been identified, converge to a set of conclusions regarding the causes of ineffective quality program implementation. The first important step in understanding the problem taken by the QA team was to develop a function model of the quality assurance system. The function model, known as a Function Analysis Systems Technique (FAST) model, formed the basis from which several analyses were performed. FAST is a methodology that comes from Value Management, or Value Engineering (VE), and is known as "Value Managed Failure Analysis." This method is comparable to Failure Modes and Effects Analysis (FMEA).

FAILURE MODES AND EFFECTS ANALYSIS WITH FUNCTION ANALYSIS SYSTEMS TECHNIQUE (FAST)

As in FMEA, FAST facilitates clear definition of the problem and identification of the system's function(s) and the critical functions required to support the basic function. The definition of a basic function 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.[2]

Failure Modes and Effects Analysis(FMEA) is an important methodology that can be integrated with the VE Job Plan to generate superior results from the methodology. The point at which FMEA is most appropriate is after the function analysis and FAST Model has been built and functions for improvement have been chosen. An understanding of the product or process under consideration is important to have clearly articulated. This is accomplished in the FMEA approach by creating a block diagram of the product or process. In VE, the FAST Model of the product/process is developed. This diagram shows major components or process functions as blocks connected together by lines that indicate how the functions are related. The FAST diagram constructs the logical relationships of Functions and establishes a structure around which the FMEA can be developed.

In FMEA, a failure mode is defined as the manner in which a component, subsystem, system, process, etc. could potentially fail [or has failed] to meet the design intent. A failure mode in one component can serve as the cause of a failure mode in another component. This is a basic premise of FAST since it is a logic diagram, by definition, any function that fails on the critical path will prevent the system from achieving its objective and the system will fail. Isolating functions that have failed is a crucial first step in the FAST approach to FMEA. Then, failure modes should be listed for function of each component or process step. This is generally accomplished through brainstorming the potential causes of failure. At this point the failure mode should be identified whether or not the failure is likely to occur.

Once the failure modes are listed, a numerical ranking established for the severity of the effect. The intent of the ranking is to help the analyst determine whether a failure would be a minor nuisance or a catastrophic occurrence to the customer. This enables the engineer to prioritize the failures and address the real big issues first. Then, the causes for each failure mode are identified. A failure cause is defined as a design weakness that may result in a failure, or it can be the cause of an actual event if using this method in a root cause analysis mode. The potential causes for each failure mode should be identified and documented. The causes are listed in technical terms and not in terms of symptoms. A numerical weight should be assigned to each cause that indicates how likely that cause is. A common industry standard scale uses 1 to represent not likely and 10 to indicate inevitable.

Next, controls that can be used to prevent the occurrence of function failure are identified. Testing, analysis, monitoring, and other techniques are identified that can or have been used on the same or similar products/processes to detect failures. Each of these controls are assessed to determine how well it is expected to identify or detect failure modes.[3] In VE, ways to prevent occurrence of function failure are developed in the creativity phase of the job plan when brainstorming ideas for improvement of the system.

After a new product or process has been in use previously undetected or unidentified failure modes may appear. FAST with FMEA should then be updated and plans made to address those failures to eliminate them from the product/process. In the following example, FAST with FMEA was used to isolate system failures in the QA program at the INL.

FAST/FMEA ANALYSIS OF PROBLEMS WITH QUALITY ASSURANCE

Once a FAST model (Figure 1 through 1b) was constructed that represented the QA process of "Improve Quality Performance" at the INL, a representative sample of the deficiencies were mapped to the functions. These deficiencies represent failure modes attributed to each function which can then be used for further analysis and development of corrective actions. (Note: A deficiency may be mapped to more than one function.) A Pareto analysis (see Figure 3), ranking the functions according to the number of "hits" each receives. This technique then yields a prioritized list of functions that need to be improved. The team then concentrated on the 20% of the functions that represent 80% of the "hits" resulting from each deficiency. The next step in this process was to identify potential causes as to why these functions are not functioning properly. Gathering of human factors information, interviews with employees involved, and review of circumstances surrounding the initial deficiencies was explored. Then, this information was linked back to the functions and brainstorming improvements took place and alternatives developed that lead to improvements in quality performance.

Once the FAST model was developed, a sample of 519 Deficiency Reports (DRs) contained in the Issue Communication and Resolution Environment (ICARE) database for FY-2001 was analyzed by comparing the information contained in the DRs to the functions identified in the FAST model to determine those functions affected by the deficiency. This information was collected and analyzed statistically to identify whether certain functions were more likely to be associated with deficiency than others were. The key problem areas that emerged from this analysis were:

- Implement Procedures and Work Control Docs
- Perform Work per Controls
- Complete Training
- Establish Controls
- Understand Applicable Procedures
- Define Requirements
- Train Workers
- Develop Work Scope
- Understand Drivers
- Document Requirements
- Understnd Process & Procedure Implementation
- Analyze Task
- Perform to Expectations
- Define Risk
- Train Supervisors
- Manage Changes
- Define Roles & Responsibilities

Function Analysis System Technique (FAST) Model
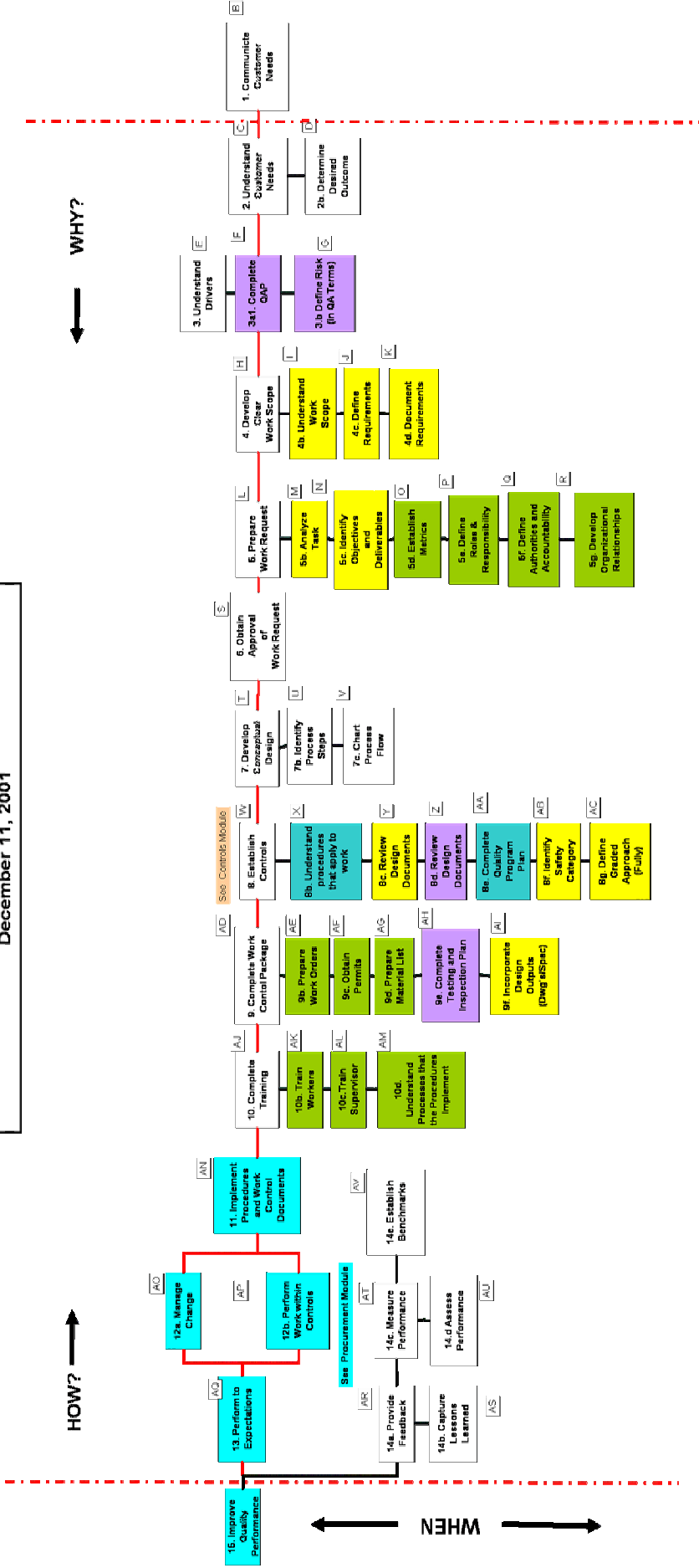Quality Assurance Improvement
December 11, 2001

WHY?

HOW?

WHEN

1. Communicate Customer Needs

2. Understand Customer Needs
2b. Determine Desired Outcome

3. Understand Drivers
3a1. Complete QAP
3b Define Risk (in QA Terms)

4. Develop Clear Work Scope
4b. Understand Work Scope
4c. Define Requirements
4d. Document Requirements

5. Prepare Work Request
5b. Analyze Task
5c. Identify Objectives and Deliverables
5d. Establish Metrics
5e. Define Roles & Responsibility
5f. Define Authorities and Accountability
5g. Develop Organizational Relationships

6. Obtain Approval of Work Request

7. Develop Conceptual Design
7b. Identify Process Steps
7c. Chart Process Flow

See Controls Module

8. Establish Controls
8b. Understand procedures that apply to work
8c. Review Design Documents
8d. Review Design Documents
8e. Complete Quality Program Plan
8f. Identify Safety Category
8g. Define Graded Approach (Fully)

9. Complete Work Control Package
9b. Prepare Work Orders
9c. Obtain Permits
9d. Prepare Material List
9e. Complete Testing and Inspection Plan
9f. Incorporate Design Outputs (Dwgs/Spec)

10. Complete Training
10b. Train Workers
10c. Train Supervisor
10d. Understand Processes that the Procedures Implement

11. Implement Procedures and Work Control Documents

12a. Manage Change
12b. Perform Work within Controls

See Procurement Module

13. Perform to Expectations

14e. Establish Benchmarks
14c. Measure Performance
14.d Assess Performance
14a. Provide Feedback
14b. Capture Lessons Learned

16. Improve Quality Performance

Figure 1. Quality Assurance Improvement FAST Model.
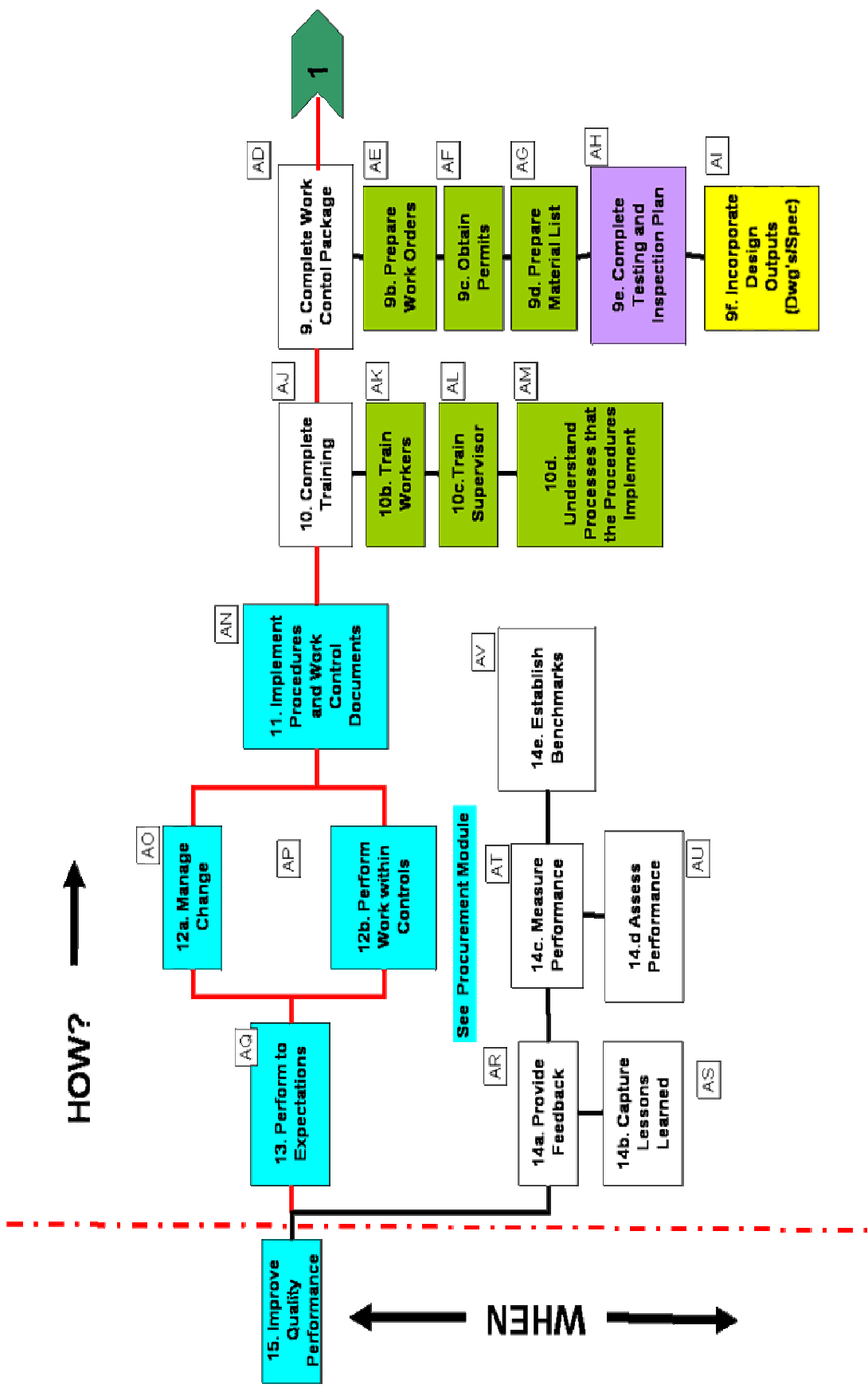
Figure 1a. Quality Assurance Improvement FAST Model (Left Side).

WHY?

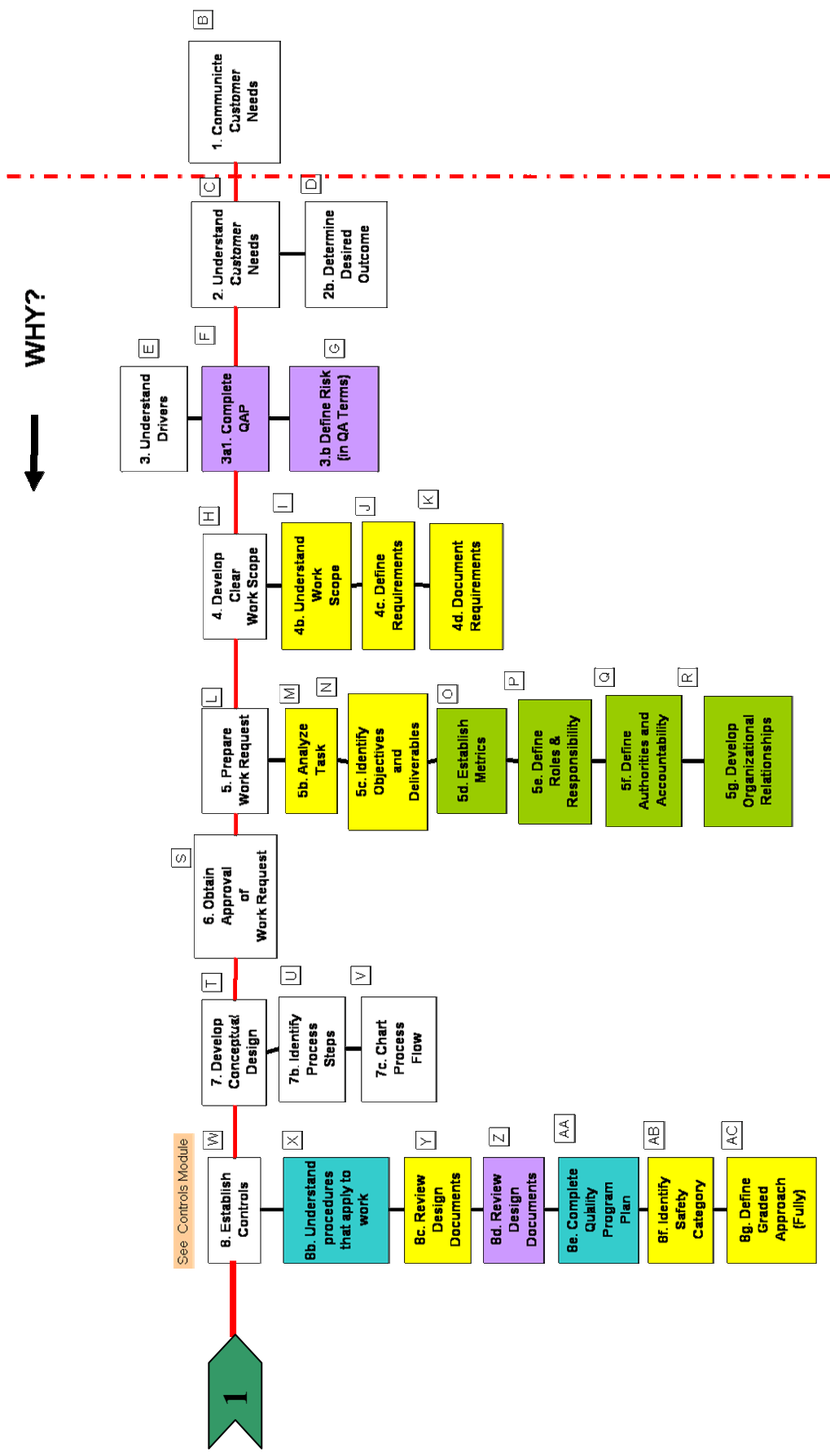1. Communicate Customer Needs [B]

2. Understand Customer Needs [C]

2b. Determine Desired Outcome [D]

3. Understand Drivers [E]

3a1. Complete QAP [F]

3.b Define Risk (in QA Terms) [G]

4. Develop Clear Work Scope [H]

4b. Understand Work Scope [I]

4c. Define Requirements [J]

4d. Document Requirements [K]

5. Prepare Work Request [L]

5b. Analyze Task [M]

5c. Identify Objectives and Deliverables [N]

5d. Establish Metrics [O]

5e. Define Roles & Responsibility [P]

5f. Define Authorities and Accountability [Q]

5g. Develop Organizational Relationships [R]

6. Obtain Approval of Work Request [S]

7. Develop Conceptual Design [T]

7b. Identify Process Steps [U]

7c. Chart Process Flow [V]

See Controls Module

8. Establish Controls [W]

8b. Understand procedures that apply to work [X]

8c. Review Design Documents [Y]

8d. Review Design Documents [Z]

8e. Complete Quality Program Plan [AA]

8f. Identify Safety Category [AB]

8g. Define Graded Approach (Fully) [AC]

Figure 1b. Quality Assurance Improvement FAST Model (Right Side).

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DATA COLLECTION AND CORRELATION TO THE FAST MODEL FUNCTIONS

In order to determine which functions we being performed less than adequately to result in the situation at the INL, data on deficiencies was collected from sitewide deficiency tracking database for the period of FY-2001 and mapped to the functions on the FAST model. The deficiencies were randomly selected from the entire database for this period and represented 519 deficiency reports, 107 of which were classified as "Significant Condition." A Microsoft Access form (see Figure 2) with a button that corresponded to each function was developed to facilitate the mapping of the deficiencies to the functions by reading the information available in ICARE, then, deciding which functions were being performed inadequately that might have resulted in this issue, or deficiency. Alternatively, the selected issues were exported to an Excel spreadsheet and the functions were added to the heading of the table. Then, evaluators simply put an "X" in the cell that corresponded to the function. Later, the data was imported back into the MS Access database and merged with existing data. This was done to assure that the complete set of data resided in one database.

Figure 2. Microsoft Access Database Form.

**STATISTICAL ANALYSES OF FUNCTIONS FROM THE FAST MODEL**

Once the deficiencies were mapped to the functions, a report indicating the number of issues associated with each functional step in the model was created. A Pareto analysis (see Figure 3) of this data was used to prioritize the function "hits" and to give additional visibility to the problem at hand. Note that the top 17 functions were affected by 80% of the issues that contribute to the overall deficiencies in the process deal with procedures, work control, and the implementation of procedures, see Table 1. The functions that required further investigation to determine the causes of their deficiencies lie in these top 17 functions affected by 80% of the issues. This information set the stage for the Human Factors analyses, including interviews of workers and management at the site regarding how they produced quality work and performed work safely.

DATA ANALYSIS

The next analysis was to correlate the root causes and corrective actions described in the DRs to the functions identified in the FAST model to determine the relationship between them and determine the causes of the deficiencies in the performance of these functions in order to make recommendations for correcting these deficiencies.

Function	Total	% of Total	Cum %
11_Implement Procedures and Work Control Docs	308	9.3%	9.3%
12b_Perform Work per Controls	307	9.2%	18.5%
10_Complete Training	215	6.5%	25.0%
8_Establish Controls	208	6.3%	31.2%
8b_Understand Applicable Procedures	186	5.6%	36.8%
4c_Define Requirements	170	5.1%	41.9%
10b_Train Workers	160	4.8%	46.8%
4_Develop Work Scope	154	4.6%	51.4%
3_Understand Drivers	148	4.5%	55.8%
4d_Document Requirements	143	4.3%	60.1%
10d_Understnd Process & Procedure Implementation	122	3.7%	63.8%
5b_Analyze Task	118	3.5%	67.4%
13_Perform to Expectations	95	2.9%	70.2%
3b_Define Risk	88	2.6%	72.9%
10c_Train Supervisors	87	2.6%	75.5%
12a_Manage Changes	87	2.6%	78.1%
5e_Define Roles & Responsibilities	68	2.0%	80.1%

Table 1. Functions involved in 80% of deficiency reports.

Issue Pareto Chart - 1/29/2002
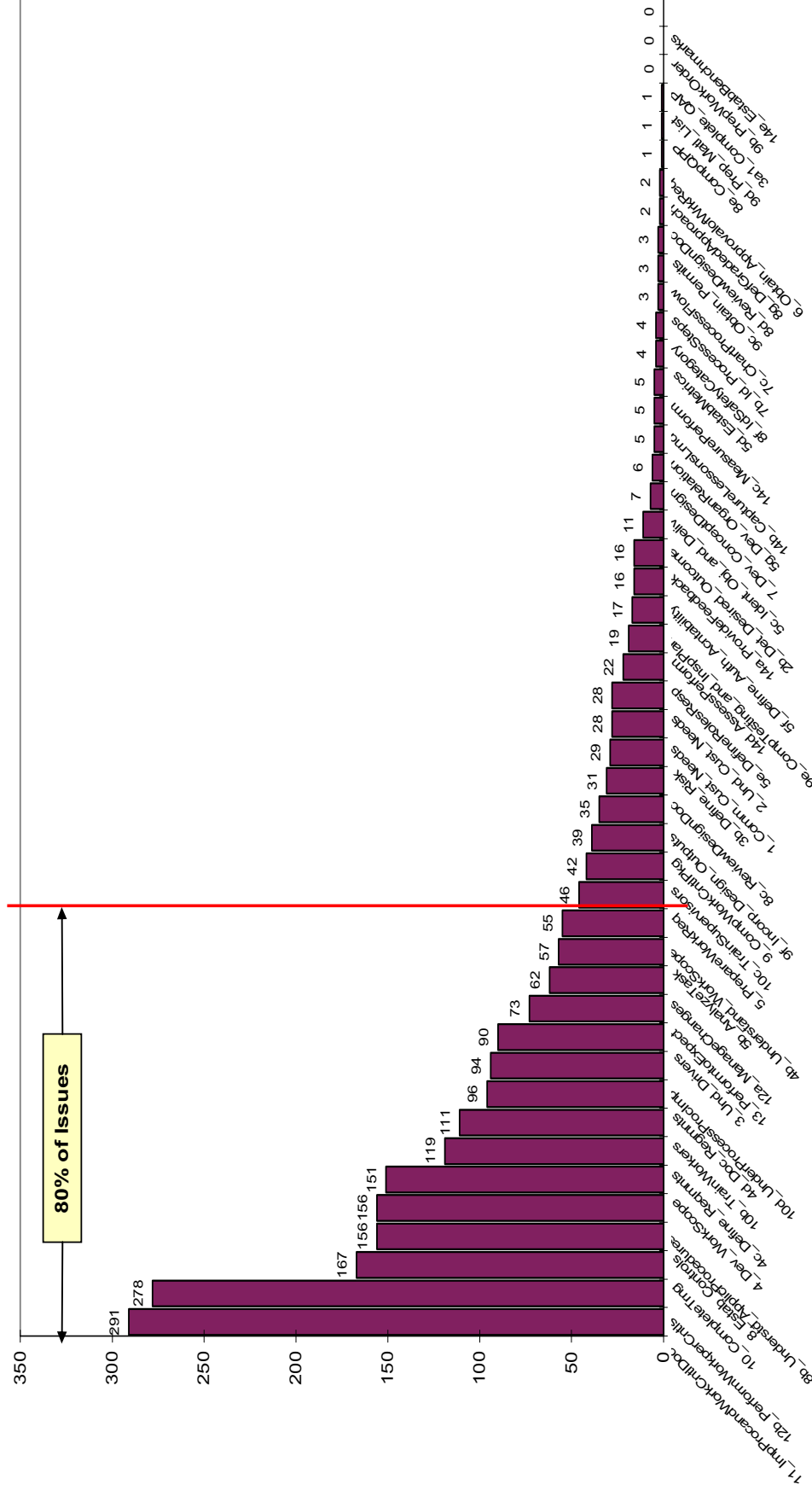
Figure 3. Deficiencies Mapped to Functions Pareto Chart.

A correlation analysis was performed to determine the nature of the relations among the various deficient functions. A relationship would be expected, given that the creation of the FAST model and the determination of functions affected occurred well after the report of the incident. In other words, given that one functional step was flagged as a problem in the deficiency report, what is the likelihood that another problematic functional step was also flagged? What is primarily of interest, however, is how related the two most frequently flagged functions are to the rest of the flagged functions. In other words, we are interested in knowing how much the other problems in the effort to produce quality work coincide with the major functions of "Improve procedures and work control documents" (Step 11) and "Perform work per controls" (Step 12b).

This analysis would indicate the effectiveness of devoting any recommendation to a single functional step, because of its impact on the other functions in the process. Table 2 below shows the total number of times (i.e., the frequencies) the most problematic functions were flagged.

Functions	Total number of times flagged
11_Implement Procedures and Work Control Docs	308
12b_Perform Work per Controls	307
10_Complete Training	215
8_Establish Controls	208
8b_Understand Applicable Procedures	186
4c_Define Requirements	170
10b_Train Workers	160
4_Develop Work Scope	154
3_Understand Drivers	148
4d_Document Requirements	143

Table 2. Most Frequently Flagged Functions.

Clearly, the frequency distribution of the issue functions of the FAST chart shows that there are some functions that are flagged more often than other functions. For example, these data show a number of deficiency reports that flag work not being performed per controls (i.e., work is not being done via procedure). Determining how related the remaining problematic functions to Step 12b is simply a matter of looking at the number of times that particular problematic functional step and Step 12b were flagged in any single deficiency report. Table 3 below shows the totals from Table 2, the number of times the other problematic functions co-occurred with Step 12b, and the percentage of how much the other problematic functions "overlap" with Step 12b.

Functions	Total number of times flagged	Total number of co-occurrences with Step 12b	Percentage of overlap with Step 12b
12b_Perform Work per Controls	307	307	100.00%
11_Implement Procedures and Work Control Docs	308	261	85.02%
10b_Train Workers	160	107	34.85%
10_Complete Training	215	148	48.21%
8b_Understand Applicable Procedures	186	126	41.04%
8_Establish Controls	208	129	42.02%
4d_Document Requirements	143	57	18.57%
4c_Define_Requirements	170	72	23.45%
4_Develop Work Scope	154	69	22.48%
3_Understand Drivers	148	77	25.08%

Table 3. Co-occurrences with Function 12b.

The second analysis was very similar to the first, except this analysis looked at the "overlap" of Step 11 with the remaining problematic functions. Table 4 below provides the summary of the findings.

Functions	Total number of times flagged	Total number of co-occurrences with Step 11	Percentage of overlap with Step 11
12b_Perform Work per Controls	307	261	84.74%
11_Implement Procedures and Work Control Docs	308	308	100.00%
10b_Train Workers	160	90	29.22%
10_Complete Training	215	143	46.43%
8b_Understand Applicable Procedures	186	118	38.31%
8_Establish Controls	208	130	42.21%
4d_Document Requirements	143	49	15.91%
4c_Define_Requirements	170	60	19.48%
4_Develop Work Scope	154	66	21.43%
3_Understand Drivers	148	61	19.81%

Table 4. Co-occurrences with Function 11.

Both of these analyses indicated the actions that would improve QA at functions 11 and 12b would also improve QA at other functions in the QA implementation process.

**ROOT CAUSE ANALYSIS OF THE PROBLEM QA IMPLEMENTATION FUNCTIONS**

A second series of statistical analyses conducted were based on a transformation of the information available in ICARE. Analyses were performed on the adverse/significant subset of data to assess whether there were differences in the causes listed for each incident as a function of the FAST step (see Figure 2). Functions 11 (Improve procedures and Work Control Documents) and 12b (Perform Work per Controls) were noted to have the highest number of incidents. Because these stages are further toward the 'nuts and bolts' stage of the FAST process, this finding had led the QA team to the conclusion that the basis of the the deficiency was not due to a problem with the method used to

insure quality (the process, per se), but in the way in which the process was implemented. However, as shown by the previous dependency analysis, incidents were also associated with stages earlier in the process, such as 'establish controls,' and 'define requirements'.

Figure 3 (see below) lists the root and apparent causes for incidents that influenced stage 11 (Improve Procedures and Work Control Documents) of the FAST process, while Figure 4 illustrates the causes affecting stage 12b (Perform Work per Controls). The caveat is that a root cause analysis was only performed for the incidents labeled as 'adverse conditions.' The cause listed for the significant conditions was the apparent cause selected by the person reporting the incident. Furthermore, for the significant incidents, multiple apparent causes could be selected.

For functions 11 and 12b, the most commonly attributed cause is 'inattention to detail.' However, as a root cause on which to base corrective actions, this cause is not highly useful because it does not indicate what type of corrective action could be taken to prevent the incident from occurring with a different worker or in a slightly different situation. Similarly, the second most frequently ascribed cause for both of these stages is 'procedure not used or used incorrectly.' However, this cause does not indicate why the procedure was not used, when it was not used, how or why it was used incorrectly. On the surface, this could imply a preponderance of incidents in which a worker was faulted for using a type 2 procedure as a type 3 procedure, or signing off on a type 1 procedure all at once, rather than as each step was performed, or it simply could imply that verification that the procedures is being used is the most common performance check used. The exact nature of these incidents cannot be determined from these data. This is an interesting consideration in light of the discussion of interview data that indicates that the perception of the purpose of procedures varies among work groups.

Continuing this line of investigation, the overall numbers of incidents attributed to each cause category was calculated. This can be seen in Figure 5. Once again, the most commonly selected causes for error are 'inattention to detail' and 'procedure not used or used incorrectly,' which are not indicative of actions that can be taken to correct deficiencies.
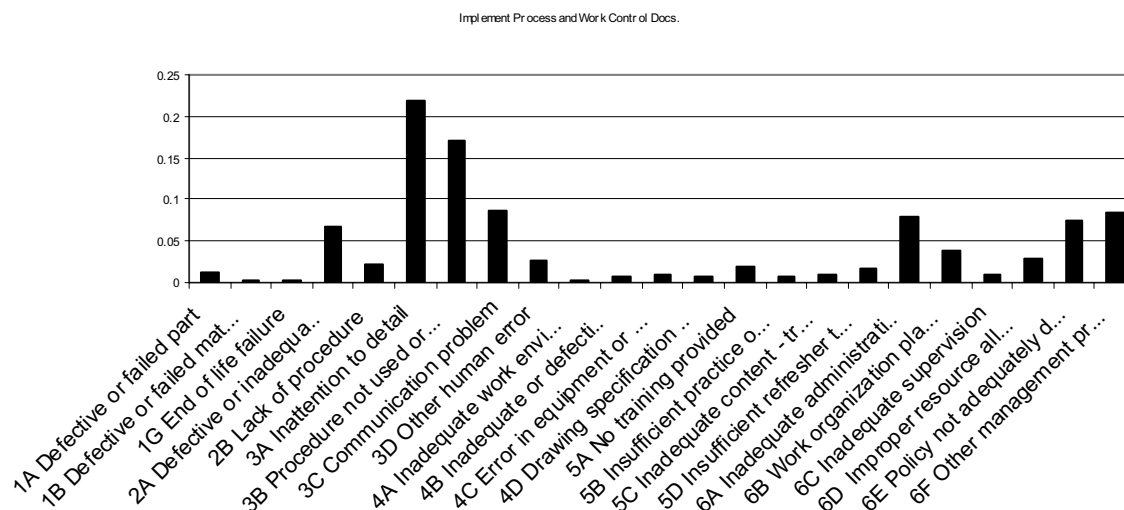
Figure 3. Proportion of incidents attributed to each root cause for FAST function 11.

12b Perform Work per Controls
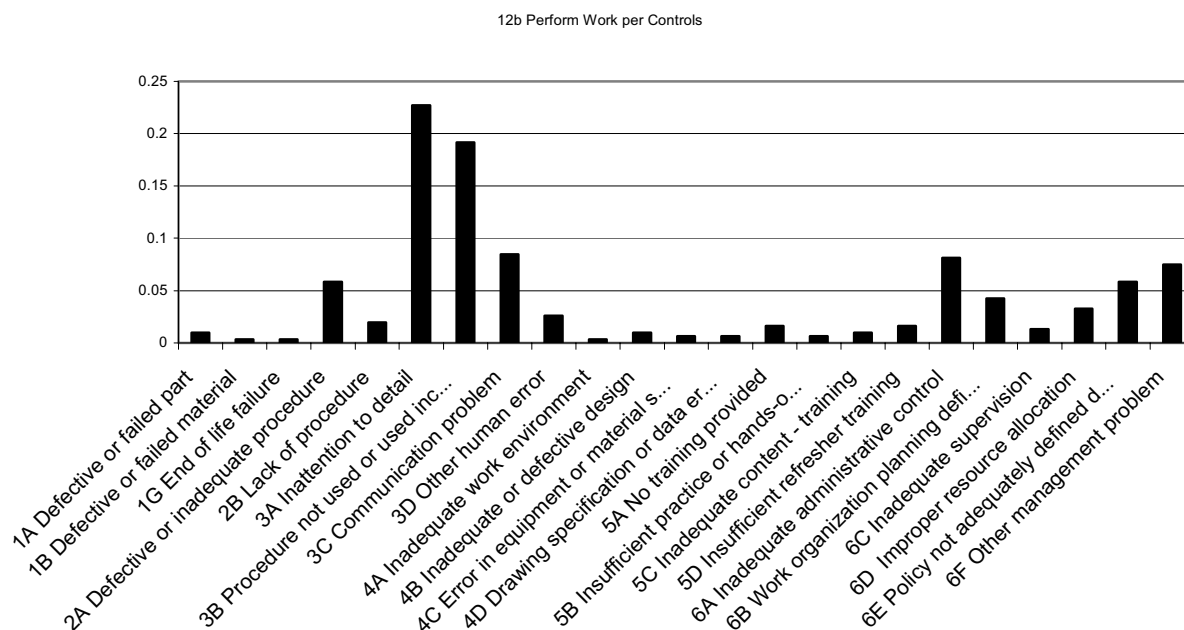
Figure 4. Proportion of incidents attributed to each root cause for 12b, Perform Work per Controls.

Number of incidents attributed to each cause category
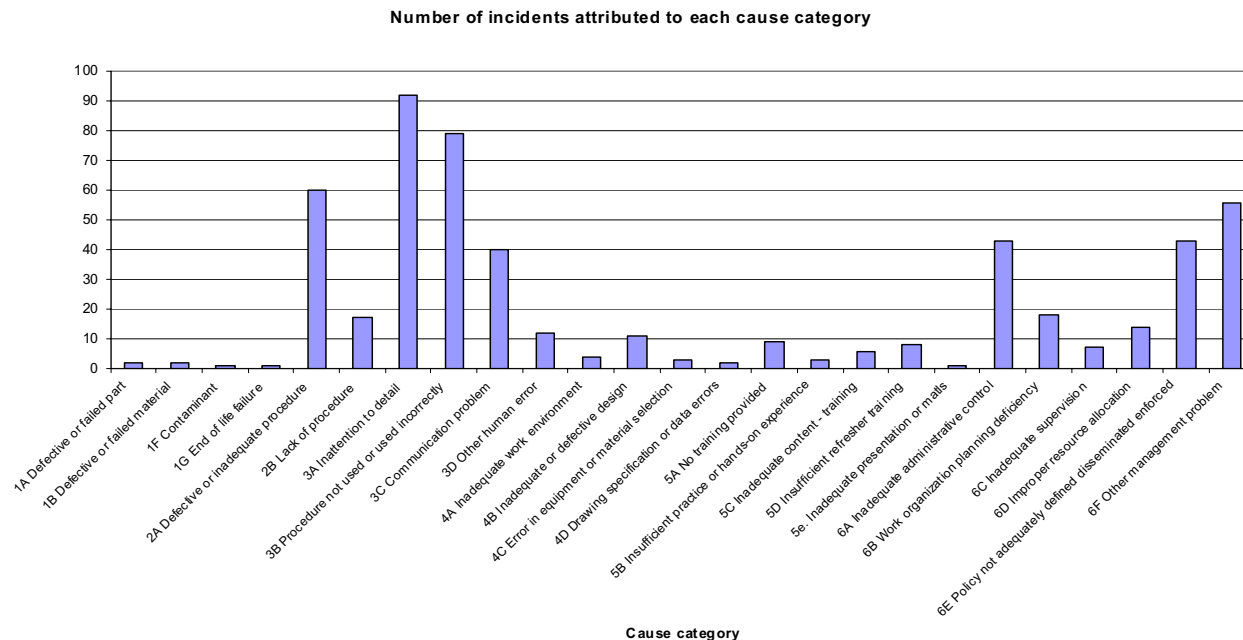
Cause category

Figure 5. Number of incidents, total, attributed to each cause category.

The frequency of inattention to detail as a cause of error indicated a need to investigate whether there were problems with procedural compliance, as suggested by the QA team and by the frequent indication of failure to use procedure as an error cause.

An insightful picture emerges when the second and third most frequently ascribed causes, 'defective or inadequate procedure' and 'other management problem,' are considered. Again, the finding of defective procedures as a commonly recognized cause was compatible with the hypothesis that procedural noncompliance occurs because of poor procedure writing. The fourth most commonly ascribed cause, 'policy not adequately defined, disseminated, or enforced,' did begin to define a line of inquiry for a subsequent Human Factors analysis based on the recommendations of the QA team.

HUMAN FACTORS ANALYSIS

After these 'problem areas' were identified, a Human Factors team used separate techniques to converge on a problem set and verify the potential causes that were arrived at through the FMEA analysis. The human factors analysis supported the results obtained from the FAST/FMEA analysis which provided additional confidence to the conclusions of the study.

The science of Human Factors is to design systems for human use[4]. The basic assumption is as follows: If things are not working it is because the tool, in this case the system, is not usable. Therefore, the questions to be asked of the system would be: Why is it not usable, and what can be done about it?

Several different ways of framing the issues were presented to the Human Factors team. The various frames tended to reflect the experience and concerns of the Quality Assurance team. These issues were used by the Human Factors team as a starting point for the investigation. These included:

- Corrective actions did not appear to be working;
- Procedures were not being followed;
- Stop work was not being used by some, and over-used by others;
- Conflicting priorities for managers and workers created different definitions of successful work;
- Communication between groups (e.g., managers and workers) is poor; and
- The overwhelming number of procedures and requirements make it difficult to perform the work.

In addition, several causes for the above issues were suggested by members of the QA team. These included causes related to both the individual worker and to the QA system itself. Below in Table 5 is an outline of the hypothesized causes and perceived issues given to the Human Factors team to be verified at the start of the investigation. Based on the analysis performed on the issues to that point, QA believed that the source of the concern was an implementation issue rather than a process issue. These potential causes were later refined and verified by the human factors team through interviews that were conducted with employees and management. Recommendations were formulated based on input from these interviews.

Potential Causes of perceived issues presented by QA at start of investigation:
1. Workers lack of training in procedures
2. Workers lack education in procedures
3. Conflicting goals, e.g., budget, schedule, and safety
4. Workers just want to get the job done
5. No feedback, in part because there is no time to assess the effectiveness of actions
6. Everything gets reported in ICARE
7. Workers don't know the quality requirements
8. There has been no integration of requirements between facilities or existing requirements

Table 5, Potential Causes of perceived issues presented by QA at start of investigation

SUMMARY AND CONCLUSIONS

The Value Management methodology, in particular Function Analysis Systems Technique (FAST), is a powerful tool for understanding and resolving system failures. Its application, combined with Failure Modes and Effects Analysis (FMEA) and Root Cause Analysis, results in significant improvements to quality and reliability by focusing the team's attention on the functions that are contributing most to the problems, and the most likely causes of these problems. Then, the team develops ways to improve these root causes of the problems, and ways to fix the problems that have occurred along with means to prevent their reoccurrence. In this case study, the management team was able to identify key recommendations to simplify implementation of procedures, and provide effective work tools that would facilitate work performance.

The process 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. There are some additional steps added to the information phase designed to identify the problem functions and identify the most likely causes of these problems with the basic function and selected supporting functions. However, the time to perform this analysis is time well spent as this approach facilitates the brainstorming of superior ideas for improvement in the creativity phase. This is because the team has fully analyzed the most likely causes of the problems with the functions this into superior ideas for improvement.[5]

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