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Structured Problem Solving and the Basic Graphic Methods Within a Total Quality Leadership Setting: Case Study

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To improve quality and productivity, Navy and Marine organizations are adopting a management approach known as Total Quality Leadership (TQL). A key element of TQL requires the use of statistical measures and graphical techniques to improve process and product quality. This case study documents the efforts made by the Fleet Combat Direction Systems Support Activity (FCDSSA) to train a select group of employees to serve as "facilitators" in the organization's TQL system. Personnel from the Navy Personnel Research and Development Center were tasked to develop and deliver a course on "Structured Problem Solving and the Basic Graphic Methods" to a group of about 20 FCDSSA employees. The basic content of the course was structured around an existing process that was identified by the executive Steering Committee as important to FCDSSA. The process was analyzed using the Plan-Do-Check-Act Cycle and demonstrated the application of the seven basic graphic methods discussed by W. E. Deming and others. It was clear that the statistical and graphical tools presented in these training materials can be applied to most, if not all, processes. Perceptions of the training by both participants and course developers are presented, as well as recommendations for improvement of the training process.

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FOREWORD

This report was prepared by the Navy Personnel Research and Development Center (NAVPERSRANDCEN) to document its involvement in the training of structured problem solving and basic graphic methods in a Total Quality Leadership setting. This effort was funded by reimbursable work unit 98 0WR00034 under the sponsorship of Gerald C. Hoffmann, Specification Control Advocate General for the Assistant Secretary of the Navy (Ship Building and Logistics) as part of his goal to develop Productivity Gain Sharing (PGS) in Navy organizations. Midway through the project the sponsorship was transferred to the Undersecretary of the Navy, the Honorable J. Daniel Howard as part of his effort to support the implementation of PGS in a total quality environment. We wish to express our sincere appreciation to both sponsors for their support of this project.

The authors also wish to thank CAPT. L. B. Blumberg of the Fleet Combat Direction Systems Support Activity for his help in organizing and facilitating these training sessions at his command.

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SUMMARY

Problem

To improve quality and productivity, Navy and Marine organizations are adopting a management approach known as Total Quality Leadership (TQL). A large part of TQL is based on the use of statistical measures and graphical techniques to improve process and product quality. Many Department of the Navy organizations have difficulty establishing and maintaining a systematic approach to process improvement using these statistical and graphical methods.

Purpose

This case study documents the efforts made by the Fleet Combat Direction Systems Support Activity (FCDSSA) to train a select group of employees to serve as "facilitators" in the organization's TQL system. Personnel from the Navy Personnel Research and Development Center (NAVPERSRANDCEN) were tasked to develop and deliver a course on "Structured Problem Solving and the Basic Graphic Methods" to a group of about 20 FCDSSA employees. These 20 people will serve as facilitators for future Process Action Committees (PACs) assigned to improve different processes at FCDSSA. The facilitators will apply what they learned in the course to help guide the PACs.

Approach

The personnel from NAVPERSRANDCEN designed a course for 20 people (mid-level managers, supervisors, and non-supervisors) that met for 3 hours per day, Monday through Friday, for 2 weeks. The format of the course was a mixture of formal presentations, discussions, demonstrations, and group exercises. The basic content of the course was structured around a real process (software development and maintenance of the Advanced Combat Direction System (ACDS) Block 0 program) that was identified by the Executive Steering Committee (ESC) as important to FCDSSA. The process was analyzed using the Plan-Do-Check-Act (PDCA) Cycle (otherwise known as the Shewhart Cycle or the Deming Cycle) and demonstrated the application of the seven basic graphic methods discussed by W. E. Deming and others.

Plan: The first step was to identify critical product and service requirements for the major customers, and develop a process flow diagram.

Do: The next step was to identify important quality variables and develop quantifiable measures of these variables. Once the measures were developed, the group designed a plan for recording and collecting data on these measures.

Check: The group collected the data and used the graphical methods to display and summarize the results.

Act: The group selected additional process variables they believed, based on knowledge from the previous steps, were major contributors to quality. They then planned and carried out actions to gain more knowledge and improve the ACDS process.

Results

The participants claimed that the course helped to improve communication within FCDSSA (especially across departments). They saw great value in applying the statistical and graphical techniques to a real process rather than working on a set of pre-packaged, hypothetical data. How much they really learned from the course is unknown at this point, but the real test will come when they must apply their knowledge to other processes being investigated by their PACs.

From the point of view of the designers of the course (the NAVPERSRANDCEN personnel), the course was too short. It was difficult to see process improvements over a 2 week period. Ideally, the course should meet once a week or once every 2 weeks for several months. During the intervals between meetings, the students could collect data on quality measures. These data could then be summarized over a sufficiently long period to allow trends to emerge and to judge the stability of the process.

Another problem with the course, perhaps related to its brevity, was the difficulty in generating process measures. The participants seemed to have difficulty separating process measures (which are intended to be impersonal) from job performance measures (which are usually intended for individual performance reviews). Perhaps with enough experience in generating process measures, the students would become more skilled at making this distinction.

Conclusions

It is clear that the statistical and graphical tools presented in these training materials can be applied to most, if not all, processes. Surely, if something as complex and intractable as software development and maintenance can succumb to these analytic techniques, there are very few processes that will be excluded. *Any impediments to TQL and the tools of TQL are not inherent to the nature of the process.* Rather, the difficulties mostly arise from management's reluctance to change the status quo.

Recommendations

1. Organizations interested in TQL should provide training to their employees on the statistical and graphical methods for quality improvement. The course should be taught by trained personnel and should meet on a weekly or biweekly basis for several months.

2. The statistical and graphical methods can be learned effectively by applying these tools to a real process that has significance to the organization. The Executive Steering Committee (ESC), or a similar body of top managers, should be responsible for identifying the process.

3. The training should cover all of the statistical tools and graphical methods that an organization is likely to need. The training should demonstrate how these tools and techniques can be applied at several different phases of the PDCA cycle, and are not restricted to only a single phase.

4. Training should be extended over several months so that long term data can be collected. Control charts should be used to determine the stability of the process. If the process is not stable, an attempt should be made to stabilize it, if possible, before applying other charts and computations.

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INTRODUCTION

Background

To improve quality and productivity, Navy and Marine organizations are adopting a management approach known as Total Quality Leadership (TQL). This approach is based on a set of management principles and statistical methods that, when combined, reduce the factors leading to poor product quality. This action, in turn, increases productivity and reduces excessive costs (Dockstader, Doherty, & Konoske, 1989; Houston, Shettel-Neuber & Sheposh, 1986). Although some private sector companies, such as Hewlett-Packard and Nashua Corporation, have demonstrated successful application of these management principles and methodologies, there are only a few government agencies that have moved ahead with the same degree of commitment (Spechler, 1988; Walton, 1986).

In the fall of 1989, Captain Blumberg, Commanding Officer of the Fleet Combat Direction Systems Support Activity (FCDSSA), San Diego, committed his organization to implementing a TQL approach. FCDSSA requested the assistance of the Navy Personnel Research and Development Center (NAVPERSRANDCEN) in this endeavor. NAVPERSRANDCEN provided FCDSSA with TQL awareness training, implementation training, and consultation services. During FY90, NAVPERSRANDCEN researchers worked closely with FCDSSA management as implementation efforts began.

An organizational infrastructure based on cross-functional teams is basic to NAVPERSRANDCEN's TQL implementation model (Houston & Dockstader, 1988). An Executive Steering Committee (ESC) represents the highest level of management. The ESC, made up of the top managers of the organization, identifies the strategic goals for organizational quality improvement efforts. The ESC charters Quality Management Boards (QMBs) to work on significant work processes within the organization. QMBs generally consist of those middle managers responsible for a specific product or service. At FCDSSA there are three standing cross-functional QMBs: (1) Department Directors QMB, (2) Chief Programmers QMB, and (3) Planners QMB. The QMB members relate the ESC's quality improvement goals to specific outputs and processes within their span of control. The individual QMBs then organize ad hoc Process Action Committees (PACs), sometimes referred to as Process Action Teams (PATs), that collect and analyze information about work processes. PACs use basic statistical methods to analyze a process and identify potential areas for improvement.

The purpose of this paper is to document the structured problem solving and basic graphic methods training conducted at FCDSSA by NAVPERSRANDCEN researchers. Examples from an actual FCDSSA work process are used to illustrate the problem solving techniques and the graphic methods.

Organizational Overview

FCDSSA develops and maintains computer programs for the Department of the Navy. It provides life cycle support for over 50 computer programs installed at over 1,215 sites throughout the world. Located in San Diego, FCDSSA has approximately 380 military and civilian employees with an annual operating budget of over 30 million dollars.

APPROACH

Course Overview

At FCDSSA's request, NAVPERSRANDCEN developed a course that introduced the basic statistical methods. The course was designed to familiarize the studer.' with structured problem solving and the graphic methods.

Twenty employees participated in the training. Two instructors conducted a 30-hour, (3 hours per day), course given over a 2-week period. The format consisted of formal presentations, class discussion, and small group interactions. The class discussions were facilitated by idea generation techniques, such as the nominal group technique (NGT) and brainstorming.

Instructors used the Plan-Do-Check-Act (PDCA) cycle, also known as the Shewhart cycle or the Deming cycle, as the foundation for the structured problem solving approach. Shewhart (1931) developed the PDCA cycle as a way to apply the scientific method to practical problems. The instructors introduced the class to seven graphic methods (flow charts, cause-and-effect diagrams, Pareto diagrams, histograms, scatter diagrams, run charts, and control charts). The course was designed so that the participants could become familiar with the problem solving structure (PDCA) and the graphic methods as applied to an actual FCDSSA process. Table 1 outlines the topics and activities for the course.

The actual number of participants cannot be determined because some dropped out and others were added after the course began. Five of the participants had first-hand experience with the process analyzed and provided the group with valuable knowledge. The other participants represented the remaining codes (departments). It was the intent that they would acquire problem-solving expertise and knowledge about the graphic methods that they could then use for team process improvement efforts in their respective codes. Their roles as facilitators would be collateral duty. All of the participants had attended a 4-hour introduction to the basic concepts and principles of TQL.

The course materials consisted of the following:

<u>Text Book</u>:
Statistical Methods for Quality Improvement by H. Kume (1985)

<u>Selected Readings</u>:

"Managing With Statistical Methods" by J. Siegel (1982)
"Process Improvement" by R. Moen and T. Nolan (1987)
"Understanding Variation" by T. Nolan and L. Provost(1990)

Videotape: <u>A Japanese Control Chart</u> narrated by Donald Wheeler (1984)

Lesson Viewgraphs prepared by NAVPERSRANDCEN

Table 1

Course Outline

TOPIC	ACTIVITY
1. Overview of TQL Principles	Viewgraph presentation
2. Introduction to PDCA cycle	Viewgraph presentation
3. Introduction to total quality process improvement	Viewgraph presentation Group discussion
4. Overview of ACDS Block 0 process	Nominal group technique Group discussion
5. Customer identification Product/Output identification Product quality characteristic identification	Group discussion
6. Process flow chart	Deployment flow chart exercise
7. Socio-technical analysis Unit operations identification Key variance identification	Variance matrix generation
8. Cause-and-effect analysis	Cause-and-effect diagram development
9. Data collection strategies	Group discussion
10. Pareto charts and histograms	Group development and interpretation
11. Scatter diagrams, run charts, and control charts	Group development and interpretation
12. Group data collection plans	Group discussion and presentations

Note. TQL = Total Quality Leadership, PDCA = Plan-Do-Check-Act, ACDS = Advanced Combat Direction System.

Before the start of the course, the ESC (which consists of the Commanding Officer, Executive Officer, Technical Director, Plans Officer, Quality Advisor, and Senior Chief Programmer identified and prioritized customer product requirements. The fleet customer and the sponsor identified the Advanced Combat Direction System (ACDS) Block 0 process as resulting in an important product. Thus, the ESC selected it as the process to be used during the training.

Advanced Combat Direction System (ACDS) Block 0 Process

The software development plan for the ACDS Block 0 process begins when the sponsor (NAVSEA) provides high-level requirements and specifications to the program analysts at FCDSSA. For example, the sponsor might request a program that tracks 100 airplanes simultaneously. The design analyst would, in turn, take those high-level requirements and transform them into lower-level specifications for the programmers. These lower-level specifications include more detailed information, such as the algorithms needed to perform the aircraft tracking function and how that function relates to other functions in the program. Programs are then delivered to a configuration management group that maintains a library of program interfaces and functions. From there, the programs go to an internal testing department, followed by an external testing group. After passing the various system tests the programs are delivered and installed for the fleet user.

COURSE CONTENT

The course was designed so that students could use data relevant to FCDSSA as they learned about structured problem solving and the basic graphic methods. The course began with a review of the basic principles of TQL, an overview of the PDCA cycle, and an introduction to the seven graphic methods. Each graphic method was discussed within the context of the PDCA cycle. Next, students learned about the TQL Process Improvement Model (PIM), developed by Houston and Dockstader (1988). This model is an elaboration of PDCA activities and is presented in Figure 1 in the form of a flow chart. The following sections are a description of activities conducted in each phase of the PDCA cycle and what was done relevant to the ACDS Block 0 process.

Plan Phase

The first phase of the PDCA cycle is the Plan phase. During the Plan phase critical product and service requirements of major customers are identified. Flow charts and socio-technical system analysis are two tools useful during this phase.

Initial activities for the students included a discussion of Block 0 process goals and objectives and the identification of customers (both sponsors and fleet users). Then, using a "Nominal Group Technique" (a variation of "brainstorming"), the instructor worked with the students to develop a list of fleet user product requirements. Because process improvement efforts are based on these critical customer requirements, it's always important to obtain this information directly from the customers. However, in this exercise, that was not possible because the class did not have direct access to the customers. The customer requirements of the products and services from the ACDS Block 0 process generated by the class are presented in Table 2. Examples of customer requirements include: (1) user friendliness, (2) program functionality, (3) program reliability, (4) user support, and (5) availability of training. Validation of these requirements by the fleet customer was not done as part of this course for the reasons cited above. However, the Department Director QMB is currently developing a customer survey instrument to obtain information regarding the fleet customers' perceptions of the products and service they receive.

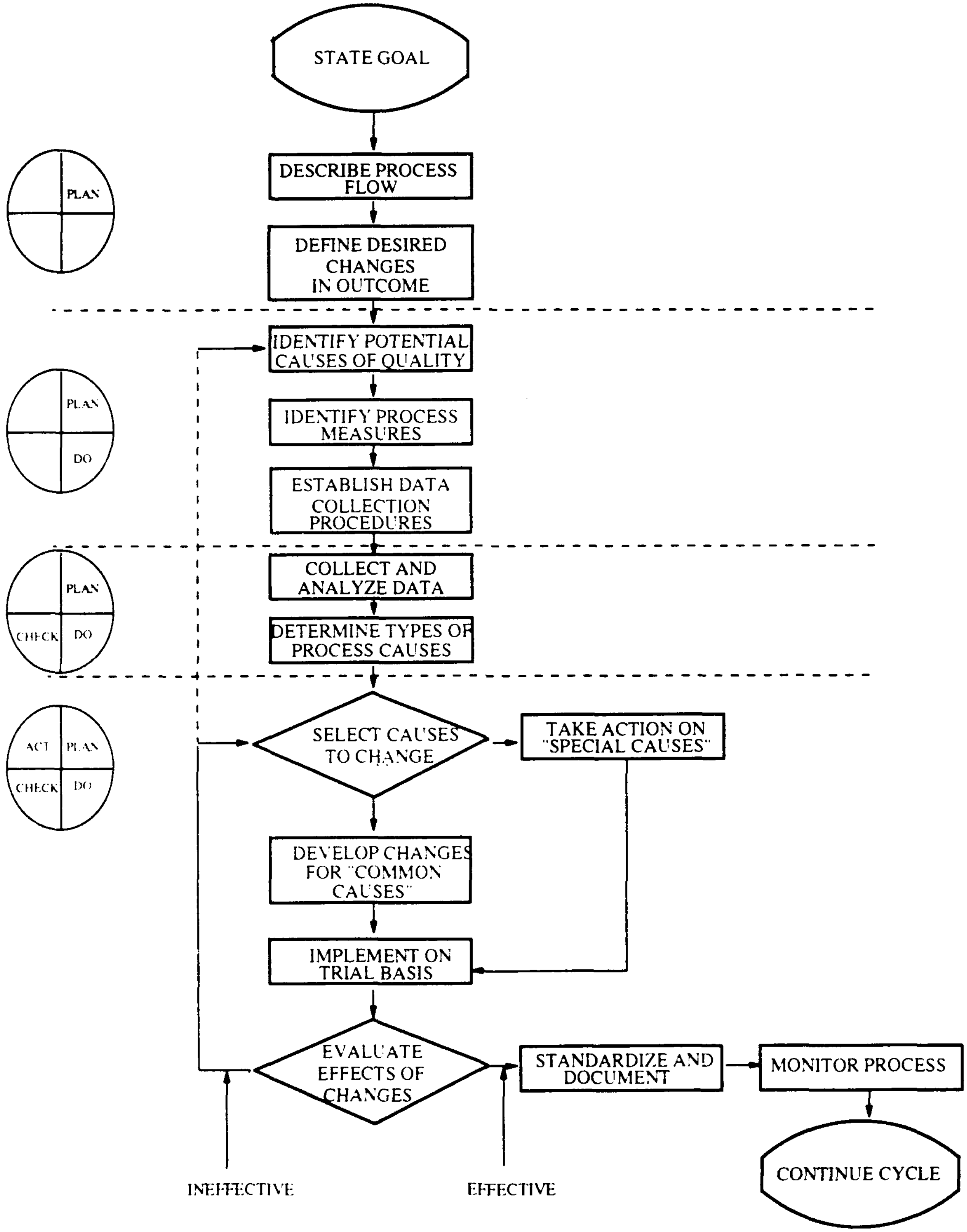

Figure 1. Process improvement model for total quality management.

Table 2

Customer Requirements for Products/Services for Advanced Combat Direction System (ACDS) Block 0 Process (Results of Nominal Group Technique)

Training

- Quantity
- Simulator
- Lock step

User Friendliness (Makes job easier)

- Logical flow of operator functions
- Useful system tools
- Good human engineering
- Flexibility (e.g., adjustable to user experience)
- Tailored (customized displays)
- Consistency of procedures

Functionality (Meets or exceeds stated user requirements)

- Adequate data links
- Effective direction of combat in complex environments
- Robust programs
- Programs work in concert with manuals
- Effective system tools for job
- Accurate real world mapping displays
- Casualty mode (graceful degradation)
- Flexible (customized displays)
- Accurate real-time displays

Reliability

- Accurate/Consistent data
- Durable programs (Large mean-time-between-failure)
- Adaptable programs (graceful degradation)
- Diagnostic capabilities (trouble-shooting by operator)
- Accurate real-time displays

Support

- Availability of resources (software, hardware, supplies)
- Assistance (user support)
- Maintenance
- Diagnostic tools

Table 2 (Continued)

Documentation

- Accurate manuals
- Record of program fixes

Technology

- Fast program updates
- State-of-the-art systems
- Open architecture

Feedback

- Opportunity for input for future capabilities
- Organization as user advocate
- Feedback acknowledged by a real person

Configuration Control

- Consistent procedures for changes and updates

Cost

- Life cycle costs
- Low space/Weight devices

Delivery

-Timeliness

In the context of the ACDS, the sponsor can also be thought of as a customer. Therefore, product/service quality characteristics for the sponsor were also generated, this time using a more traditional brainstorming session. The results of that group process are presented in Table 3. Following this brainstorming session, the group decided to work on a requirement that was important to both the sponsor and fleet user. This requirement was the *functionality of the computer programs*. Table 4 presents a list of possible product or output measures of functionality for ACDS Block 0 programs. Examples of output measures for program functionality include: (1) the number of functions the program performs correctly, (2) the mean time between program failures, and (3) the number of times the operator must intervene to maintain the program in operation. This list was generated using another brainstorming session.

Table 3

Sponsor Product/Service Requirements for Advanced Combat Direction System (ACDS) Block 0 Process (Generated from Brainstorming Session)

1. Cost/Dollars
2. Schedule/Timeliness
3. Specifications met
4. Reliability/Availability (system doesn't go down)
5. Availability of status reports
6. Maintainability of life cycle support
7. Flexibility of organization (change in programs, personnel)
8. Interoperability

Table 4

Product Measures of Functionality for Advanced Combat Direction System (ACDS) Block 0 Program (Generated from Brainstorming Session)

1. Number of functions done correctly
2. Mean time between failures
3. Number of times program doesn't function
4. Number of times operator intervenes
5. Number of trouble reports
6. Number of fleet messages
7. Complexity of components
8. Number of times to do unit tests
9. Length of time program runs before it fails

Another task in the Plan phase is to develop a process flow chart. A flow chart is a diagram that depicts the steps in a process and how these steps interrelate. A deployment flow chart (Tribus, 1989) graphically communicates the interrelation and sequence of operations and the decisions required to transform resources into outputs. Figure 2 shows the ACDS Block 0 process flow chart.

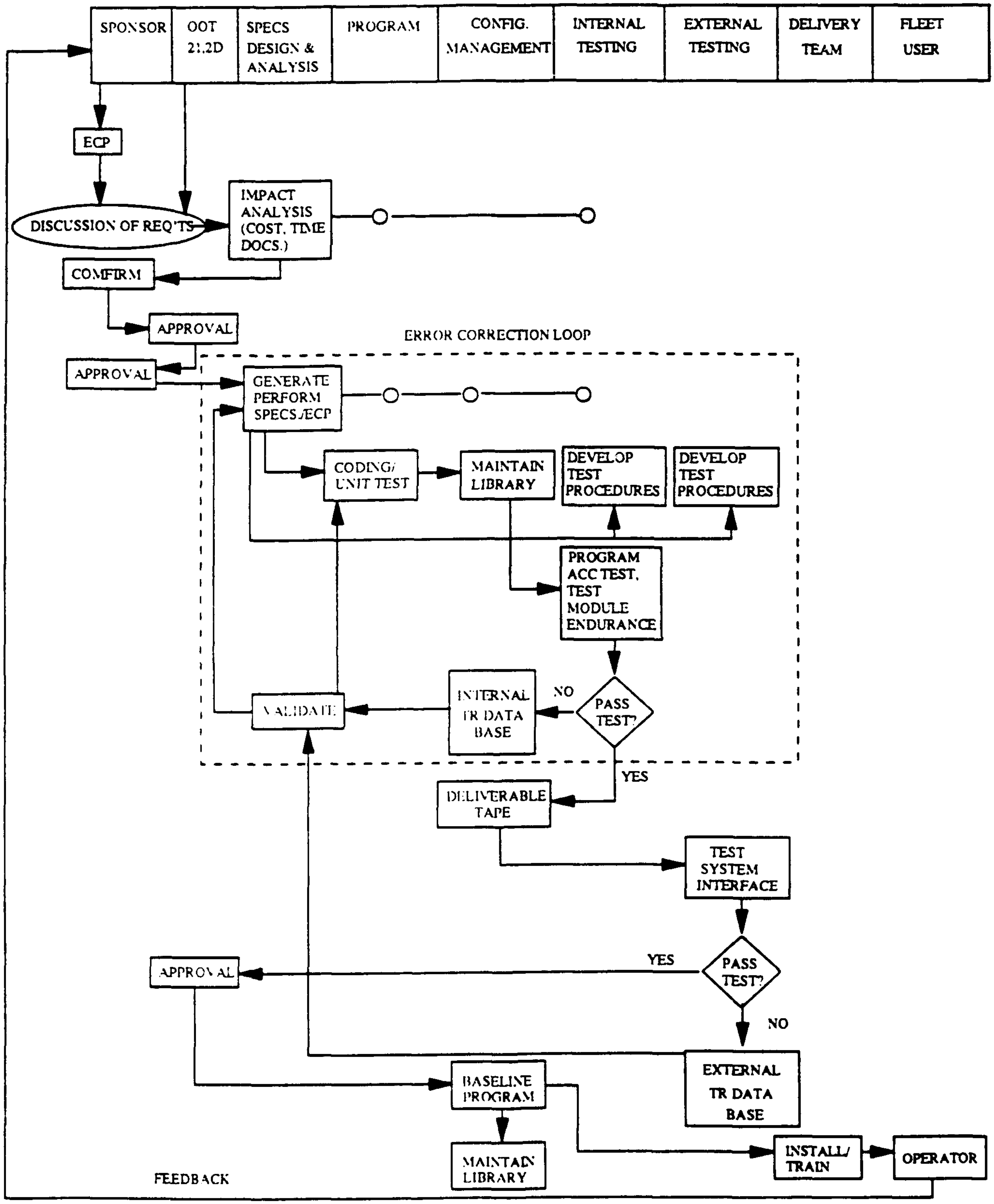

Figure 2. Deployment flow chart of Advanced Combat Direction System (ACDS) Block 0 process.

During the discussion and development of the process flow chart, the group identified such things as duplicated efforts between operations, "gaps" in accountability, overuse of inspection, and ways to streamline the process. Table 5 is a partial list of ideas generated during flow charting that were thought to have a positive effect on the ACDS process.

Table 5

Ideas for Ideal Flow Process for Advanced Combat Direction System (ACDS) Block 0 Program (Generated from Brainstorming Session)

1. Certify modules
2. Make smaller modules
3. Use structured coding
4. Show front-end concern for quality over dollars
5. Maintain accurate documentation
6. Finalize code/Design walk through
7. Send analyst with delivery team to get user feedback
8. Formalize testing process
9. Form team for up-front analysis/Design
10. Give Analyst input into testing procedures
11. Reduce number of distractions (provide more support)

Although socio-technical systems analysis is not considered one of the seven graphic methods, it was presented here as a tool for understanding how an organization transforms its inputs into outputs through the interaction of its social and technical subsystems. The technical system was analyzed by identifying the unit operations and variances. Unit operations are the activities required to bring about a change in the transformation process. Variances are those factors that create deviations from some desired outcome.

Table 6 lists the "unit operations" and "variances" for the ACDS Block 0 process. The unit operations for the Block 0 process consisted of such things as design of high-level specifications, analysis of low-level specifications, programming, and configuration management, while some of the variances identified in the Block 0 process included clarity of program performance specifications (PPS) and correctness of analysis of high-level specifications.

The next step in a technical analysis is to develop a variance matrix. A variance matrix is a chart that lists all of the variances for each unit operation. The matrix serves two purposes: (1) to show the interaction pattern of the variances and (2) to help isolate key variances. A key variance is one that stops or seriously disrupts the transformation process. Figure 3 shows a variance matrix for the ACDS Block 0 process, as developed by the students. It is incomplete because of the lack of class time, but it was recommended that they complete it in the future. Nevertheless, from the variance matrix exercise as it exists, key variances began to emerge, such as clarity and accuracy of high-level requirements and correctness of source code.

Table 6

Unit Operations and Variances for Advanced Combat Direction System (ACDS) Block 0 Process

Unit Operations	Variances
Statement of high-level requirements	(1) Completeness
	(2) Accuracy
	(3) Clarity
	(4) Volume (workload)
	(5) Timeliness
	(6) Moving targets
Analysis of low-level specifications	(1) Correctness of analysis of high-level requirements
	(2) Clarity of PPS (pseudo code)
	(3) Timeliness
	(4) Quality of operator manuals
	(5) Currency of operator manuals
	(6) Completeness of PPS
Programming source code	(1) Interpretation of pseudo code
	(2) Correctness of source code
	(3) Availability of unit testing facilities
	(4) Frequency of spec changes
	(5) Currency of master (library) program
	(6) Knowledge of hardware
	(7) Knowledge of interfaces
	(8) Source update cycle
	(9) Currency of programming tools
	(10) Timeliness
Configuration management	(1) Currency of documentation
	(2) Accuracy of TR data base
	(3) Appropriateness of TR priority
	(4) Adequacy of compiling procedures
Internal testing	(1) Quality of test facilities
	(2) Availability of test facilities
	(3) Adequacy of simulations
	(4) Interpretation of PPS
External testing	(1) Knowledge of fleet requirements
	(2) Interpretation of PPS
Delivery	(1) Availability of transport
	(2) Delivery team mix

Note. PPS = Program Performance Specifications, TR = Trouble Reports.

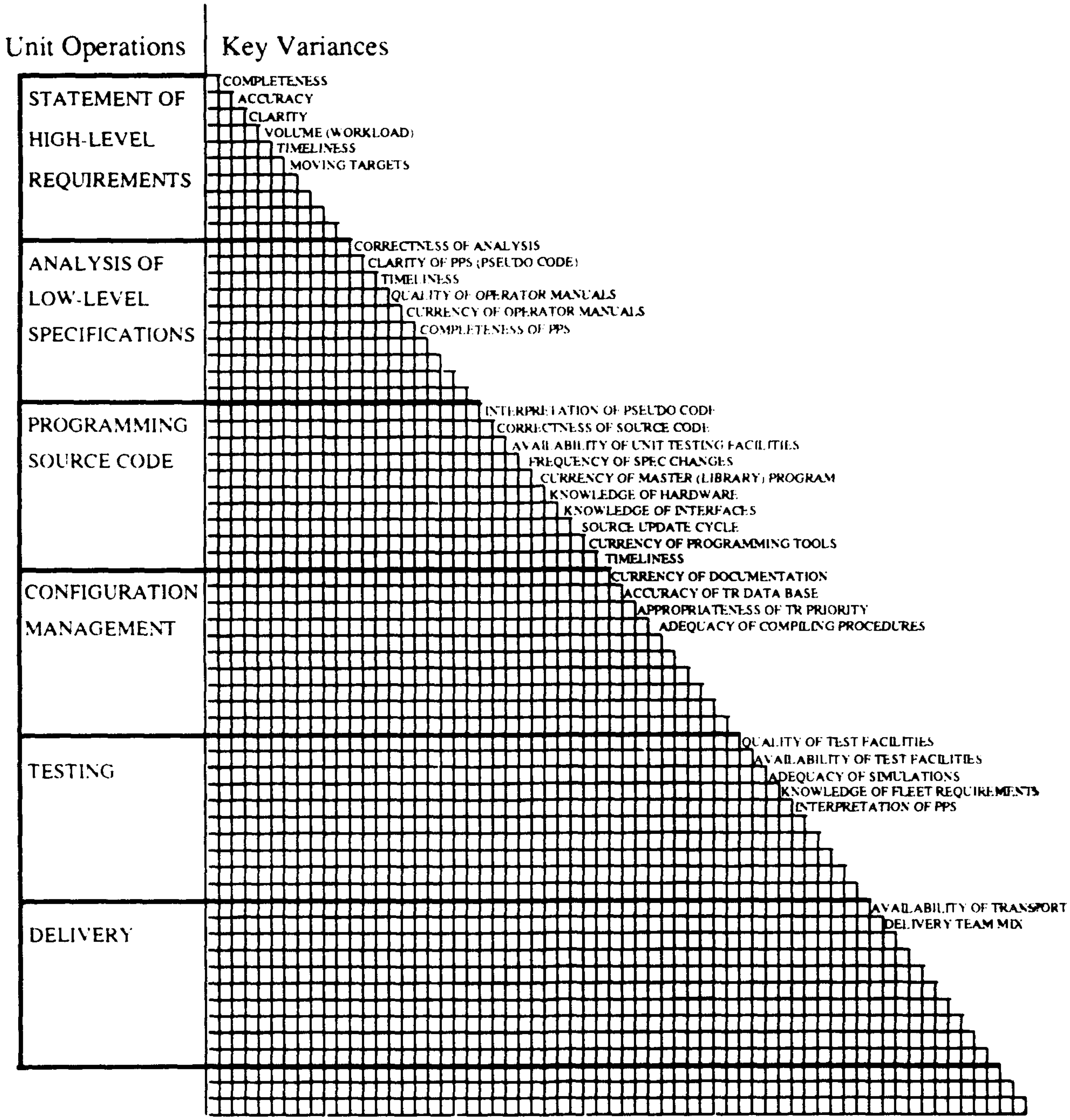

Figure 3. Partial variance matrix for Advanced Combat Direction System (ACDS) Block 0 process.

The next step was to construct a table identifying the key variances and the negative impact the variances have on the achievement of goals, the frequency of their occurrence, and their impact on output (Table 7). A variance control table was then constructed that listed the key variances and documented current control mechanisms and preliminary ideas for improvement (Table 8).

Do Phase

After quality goals have been defined, the process variables related to improved quality need to be identified. There are three major responsibilities for the team in the Do phase. First, it studies the current process and its outputs to identify variables related to quality. Second, it identifies measures of those variables. Third, it creates a format by which to record and collect data.

The purpose of conducting the cause-and-effect analysis is to identify the variables that appear to have major influence on process results. Cause-and-effect diagrams show the relationship between a given "effect" and the possible "causes" that contribute to it. Cause-and-effect diagrams are used for analyzing problems and the factors that contribute to them. A cause-and-effect diagram was developed using a product quality characteristic (program functionality) that was considered to be important to both the sponsor and the fleet user. Figure 4 shows the results from the group brainstorming session. As can be seen in Figure 4, software tools, hardware, personnel, management support, methods, and quality evaluation were identified as important "causes" of process performance. Functionality of the computer programs was the result or "effect" of the combination of variables or "causes."

As important as it is to have valid measures of outcomes (customer satisfaction/customer requirements) and outputs (products/services), it is vital to obtain process measures as well. Process measures are measures that reflect the optimization of an organization's internal processes. Precise process measures are critical because they have a direct effect on output quality. Examples of process measures for software development might include (1) the number of lines of code per program specification, (2) the amount of time spent clarifying the specification, (3) the number of unit tests per lines of code, or (4) machine downtime. Unfortunately, organizations rarely have systems established to collect data on process characteristics. When such data are not available, it is necessary to develop those process measures. Developing process measures is not easy. Although the group discussed possible measures, they were unable to come to any agreement on a set of them that would adequately reflect the ACDS Block 0 process.

Table 7
Identification of Key Variances

VARIANCE	NEGATIVE IMPACT ON GOALS? (YES-NO) QUANTITY	QUALITY	COST	TIME	HEALTH & SAFETY	FREQUENCY OF OCCURRENCE LOW	MED	HIGH	IMPACT ON OUTPUT CHRONIC	CATA-STROPHIC	AFFECTS VARIANCES (WHICH #)	KEY VARIANCE? (YES-NO)
CLARITY OF PPS	Y	Y	Y	Y	Y			X	X			
TIMELINESS OF ANALYSIS	Y	Y	Y	Y	Y			X	X	X		
CORRECTNESS OF ANALYSIS	Y	Y	Y	Y	Y		X		X			
CORRECTNESS OF SOURCE CODE	Y	Y	Y	Y	Y			X	X			
KNOWLEDGE OF HARDWARE	Y	Y	Y	Y	Y		X		X			
ADHERENCE TO PROCEDURES	Y	Y	Y	Y	Y			X		X		
CURRENCY OF PROGRAMMING TOOLS	Y	Y	Y	Y	Y			X	X			

Table 8
Variance Control Table

KEY VARIANCE	UNIT OPERATION WHERE OCCURS	WHERE OBSERVED	WHERE CONTROLLED	CONTROLLED BY WHOM	ACTIVITIES REQUIRED TO CONTROL	INFORMATION RELATED TO CONTROL	SUGGESTION FOR CHANGE
TIMELINESS OF ANALYSIS	SPEC DESIGN	PROGRAMMING TESTING	EVERYBODY				PLANNERS SHOULD CONTROL

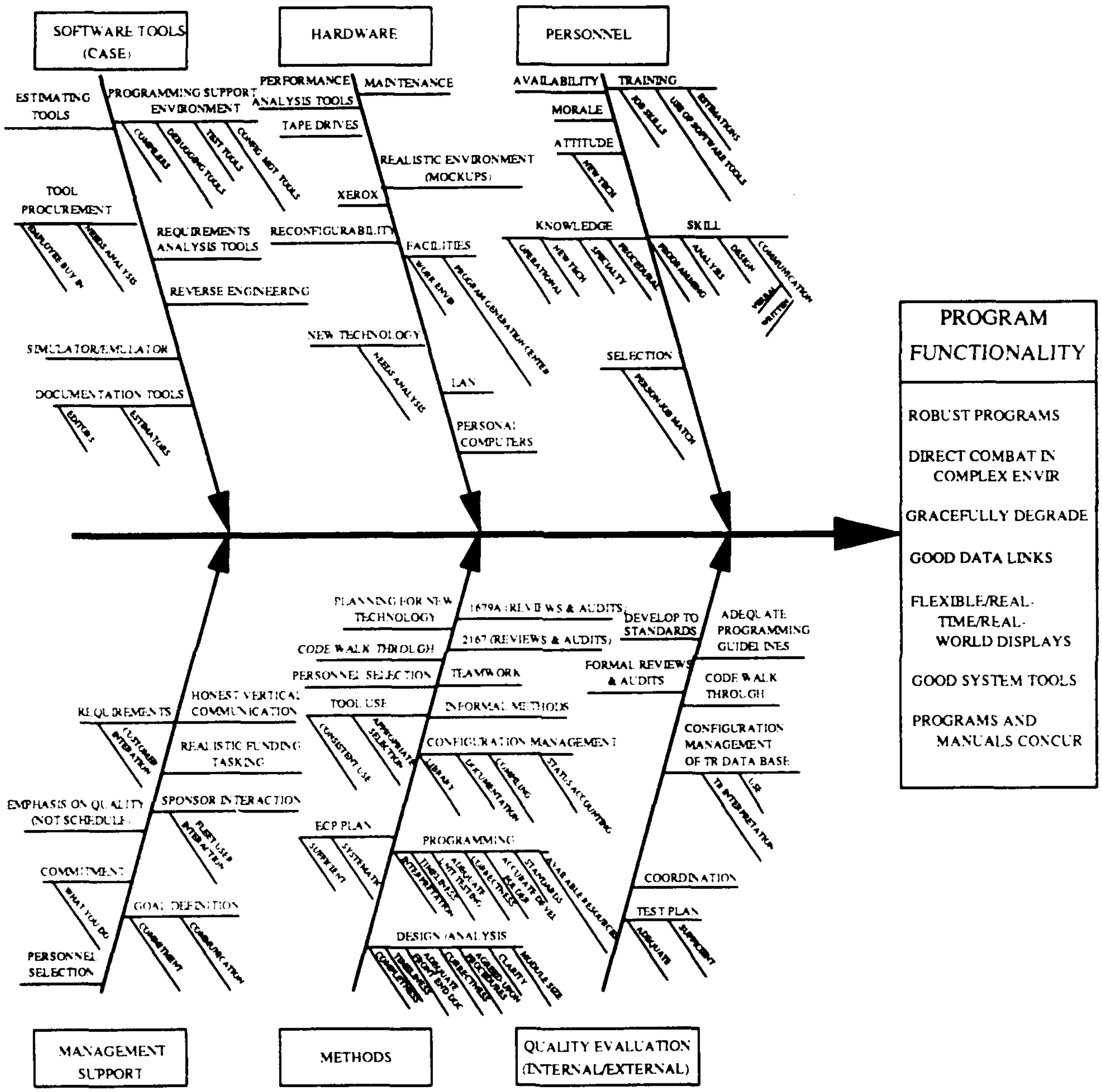

Figure 4. Cause-and-effect diagram for functionality of Advanced Combat Direction System (ACDS).

Once process measures are developed, the team must decide how to collect the data. The instructors then presented material on data collection purposes and procedures. Types of data, sampling techniques, and the use of check sheets were discussed. The first part of the data collection strategy requires the team to collect information on the "causes" of variation identified through the cause-and-effect analysis. Questions concerning *what* information will be collected, *how* it will be collected, *who* will collect it, *where* it will be collected and *when* it will be collected need to be answered. Then, using a Pareto diagram, the most important causes can be identified.

Pareto charts provide a basis for selecting "problems" on which to focus initially and indicate results of improvement efforts (baseline vice results of changes). A Pareto chart is a vertical bar graph that shows how categories are compared and ranked (see Figures 5, 6, A-1, and A-2 for examples). The bars are arranged in descending order of magnitude from left to right, and often a line is drawn from left to right that shows the cumulative frequency (see Figures 5 and 6). Sometimes the categories in a Pareto chart need to be redefined on the basis of initial results. For example, Figure 5 shows that the "other" and "document" categories are the most frequent. They are represented to the right, however, to indicate that these categories belong to other categories or should be broken down into new categories. Figure 6 shows what the Pareto chart looks like after the category adjustments are made.

Check Phase

Typically, we tend to measure the final product or service, this is our output. The customer response or reaction to the product or service is the outcome. Outcomes are indicators of how well the product or service satisfied the customers' needs. Process factors are how such things as machines, methods, material, and people interact to produce the organiation's product or service. These have been the most overlooked sources of measurement. Analyzing what occurs during this phase allows us to determine how our products and services are produced and how it can be improved.

In the Check phase teams collect process and output data and summarize the data using graphic methods. Once the data have been summarized, teams can determine which process variables have a significant effect on outputs and, subsequently, outcomes. There are five graphic methods commonly associated with process analysis: Pareto diagrams, histograms, scatter diagrams, run charts and control charts. Although these graphic methods are most appropriate for process measures, product output data already available from the organization were used in the class to illustrate their use and interpretation. The output data was in the form of Trouble Reports (TRs).

When problems are discovered in the programs generated by the Block 0 process, a TR is written. The TR goes into a database that can be examined by program analysts. Information in the database includes: a brief description of the nature of the problem, who found the problem, where the problem originated, the priority for fixing the problem, and the current status of the TR. This database was used to demonstrate the use of Pareto charts, histograms, scatter diagrams and run charts.

Figures 5 and 6 and Tables 9 and 10 show data sheets and Pareto charts created to investigate which program modules contributed the most TRs. From a review of a Pareto chart, a team could identify those variables that have the greatest effect on an output characteristic.

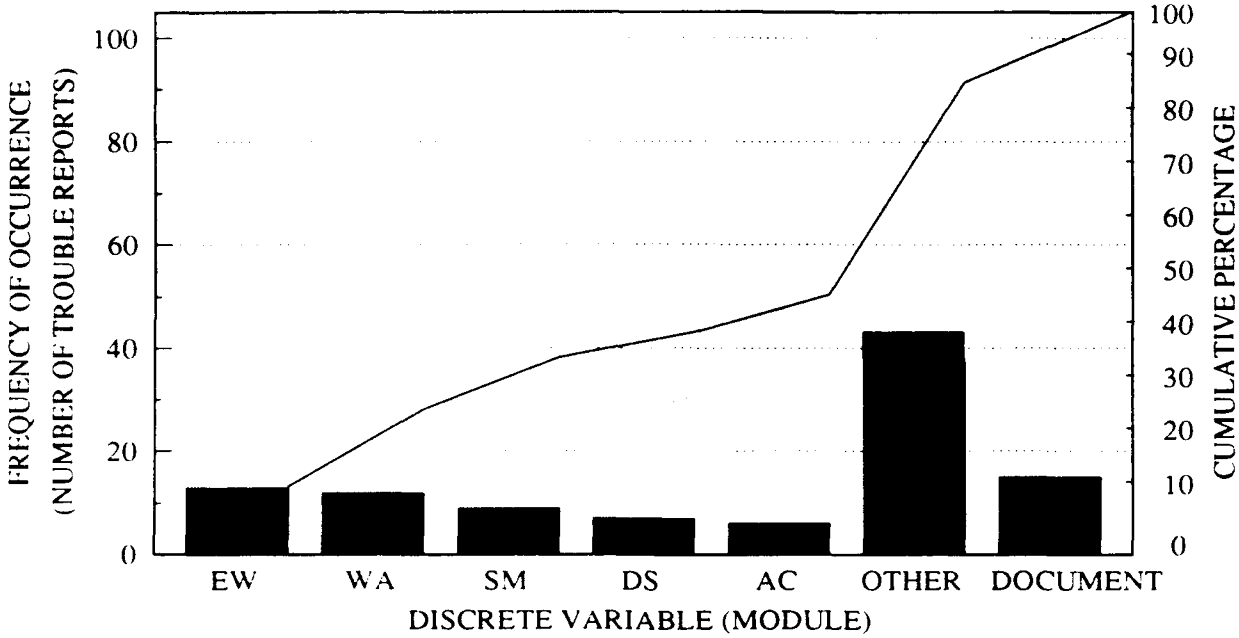

Figure 5. Pareto chart of software modules.

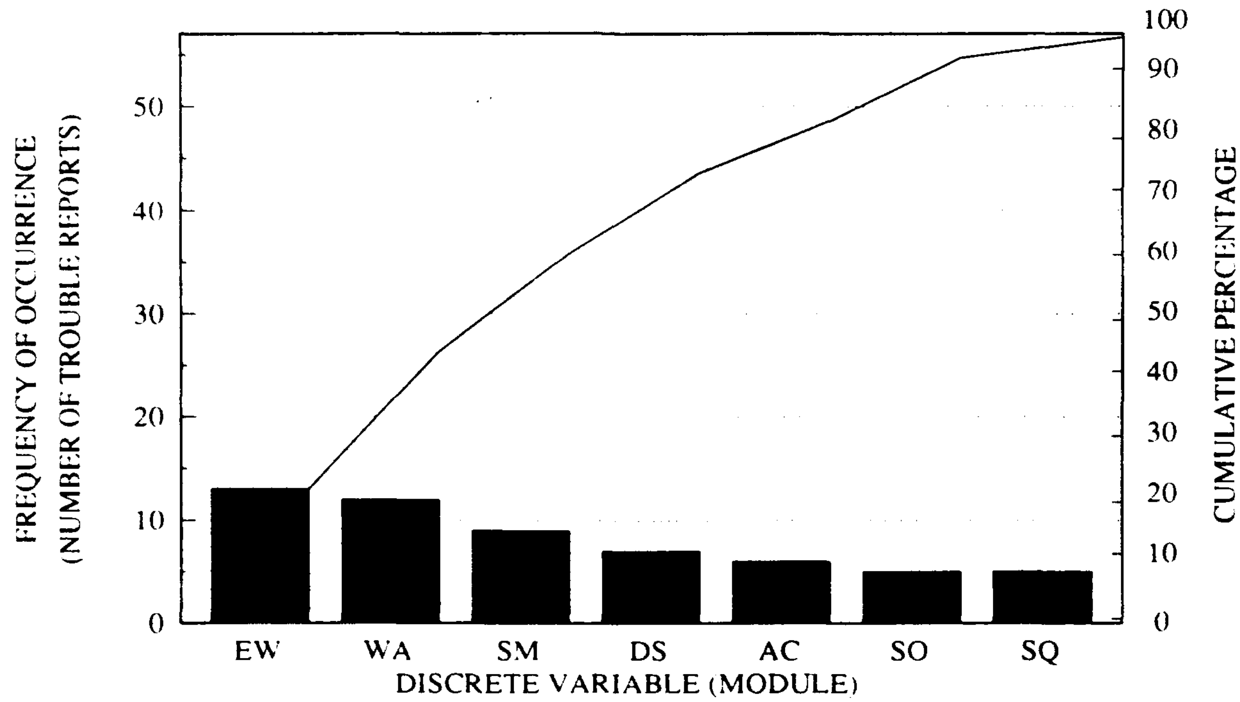

Figure 6. Pareto chart of top seven modules.

Table 9

Data Sheet for Pareto Chart (Includes Modules for all Trouble Reports)

	CATEGORY	NUMBER	CUMULATIVE TOTAL	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
1	EW	13	13	12.3	12.3
2	WA	12	25	11.4	23.7
3	SM	9	34	8.5	32.2
4	DS	7	41	6.7	38.9
5	AC	6	47	5.7	44.6
6	Other	43	90	40.9	85.[illegible]
7	Document	15	105	14.5	100.0

Table 10

Data Sheet for Pareto Chart (Top Seven Modules)

	CATEGORY	NUMBER	CUMULATIVE TOTAL	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
1	EW	13	13	23	23
2	WA	12	25	21	44
3	SM	9	34	16	60
4	DS	7	41	12	72
5	AC	6	47	10	82
6	SO	5	52	9	91
7	SQ	5	57	9	100

Histograms are used to characterize variables that are measured and provide a snapshot of the variation in the measured characteristic. Histograms can be used to depict variation in process performance or results. A histogram is a bar graph that summarizes a large set of data along a continuum. Figure 7 presents a histogram that depicts the frequency of occurrence of TRs of different priorities (most critical or severe). The chart shows that TRs with priority of 3 or 4 are the most frequent.

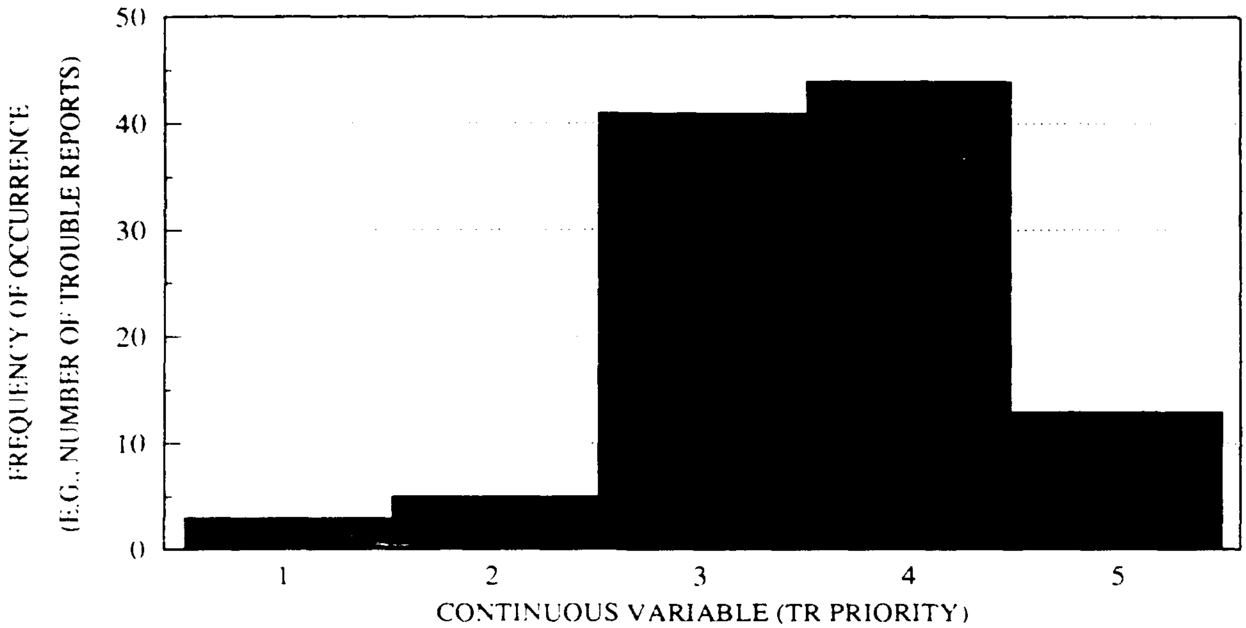

Figure 7. Histogram of TR priority.

Scatter diagrams are often used to check the strength of the possible "cause-and-effect" relationships identified in the Do phase. Scatter diagrams show the relationship between two variables that have been paired on some basis. The shape of the pairing of points in the scatter diagram (often a statistical procedure is used to derive a "line of best fit") indicates whether the two variables are related. Figures 8 and 9 depict scatter plots (scatter diagrams) of TRs. Figure 8 shows the relationship between TR priority and days-in-status for TRs generated from internal testing groups, while Figure 9 displays the same relationship for TRs generated by external testing groups.

A run chart is shown in Figure 10. Run charts are constructed to determine if there are time-related patterns in process performance. They can also be used to test "before" and "after" effects of process changes. Figure 10 presents the number of TRs generated for an eleven day stretch.

Control charts depict process performance from samples taken over a period of time. They can be used to predict how a process should perform under stable conditions. These charts can be used to distinguish between variables that consistently affect all of the outputs of a process (called "common causes") and those that affect outputs in an unpredictable way (called "special causes"). Control charts were discussed following the viewing of a film titled "A Japanese Control Chart". Participants then constructed X bar and R charts using hypothetical data. Because we did not have access to a sufficient amount of data to construct an actual control chart on the ACDS Block 0 process, the participants constructed control charts using sample data from an in-class exercise (Figure 11).

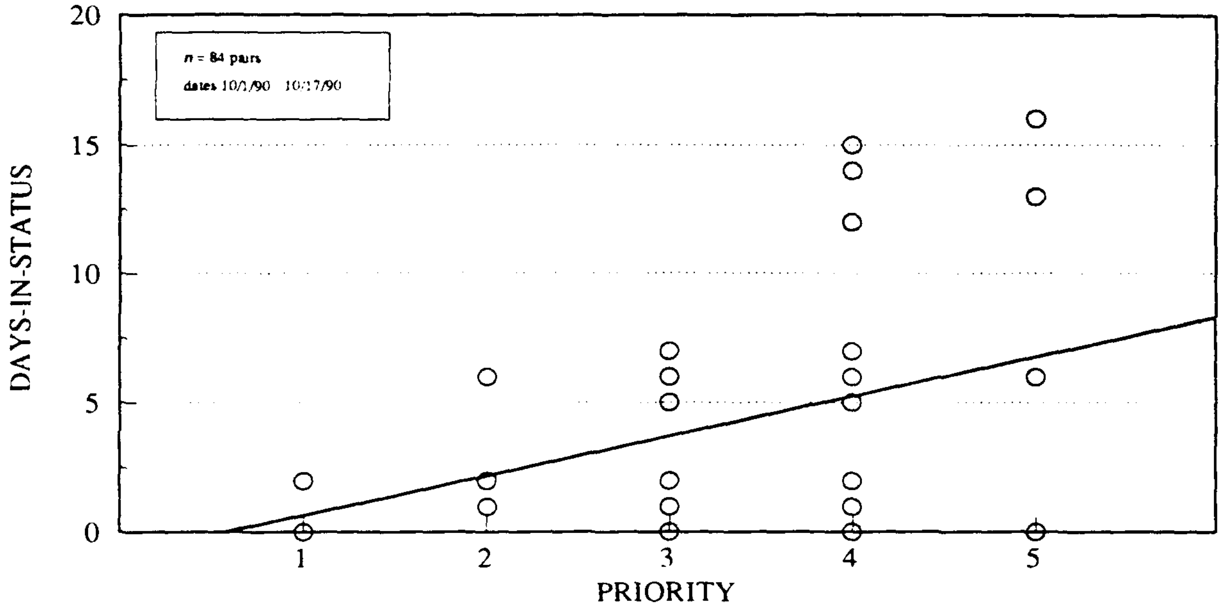

Figure 8. Scatter plot of priority and days-in-status for internal Trouble Reports.

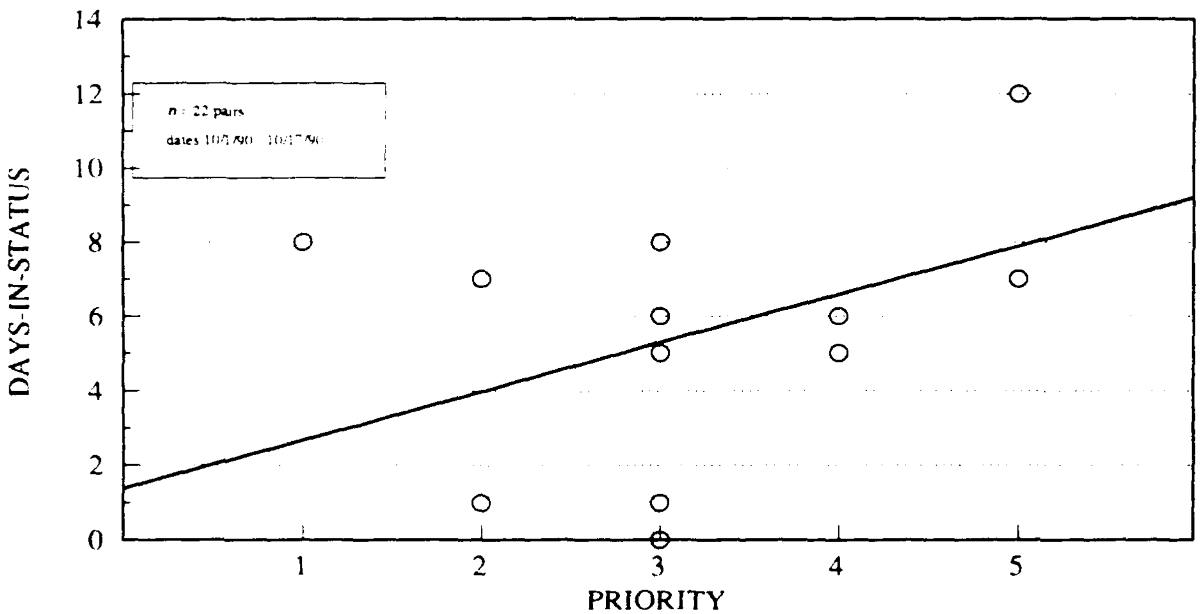

Figure 9. Scatter plot of priority and days-in-status for external Trouble Reports.

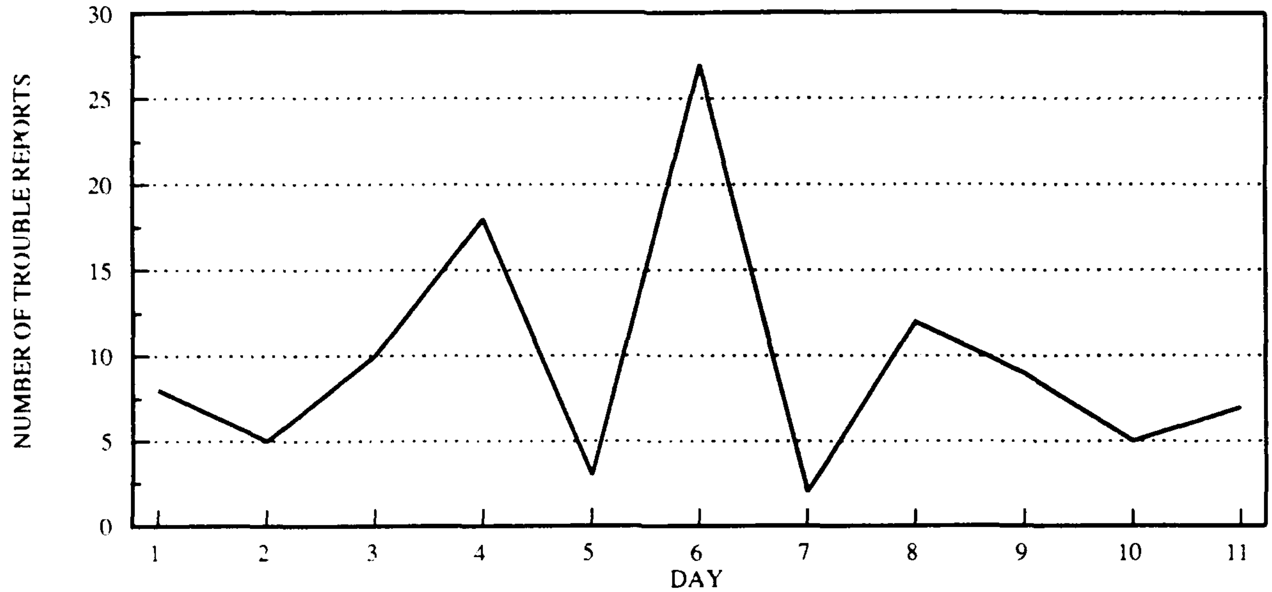

Figure 10. Run chart of TRs.

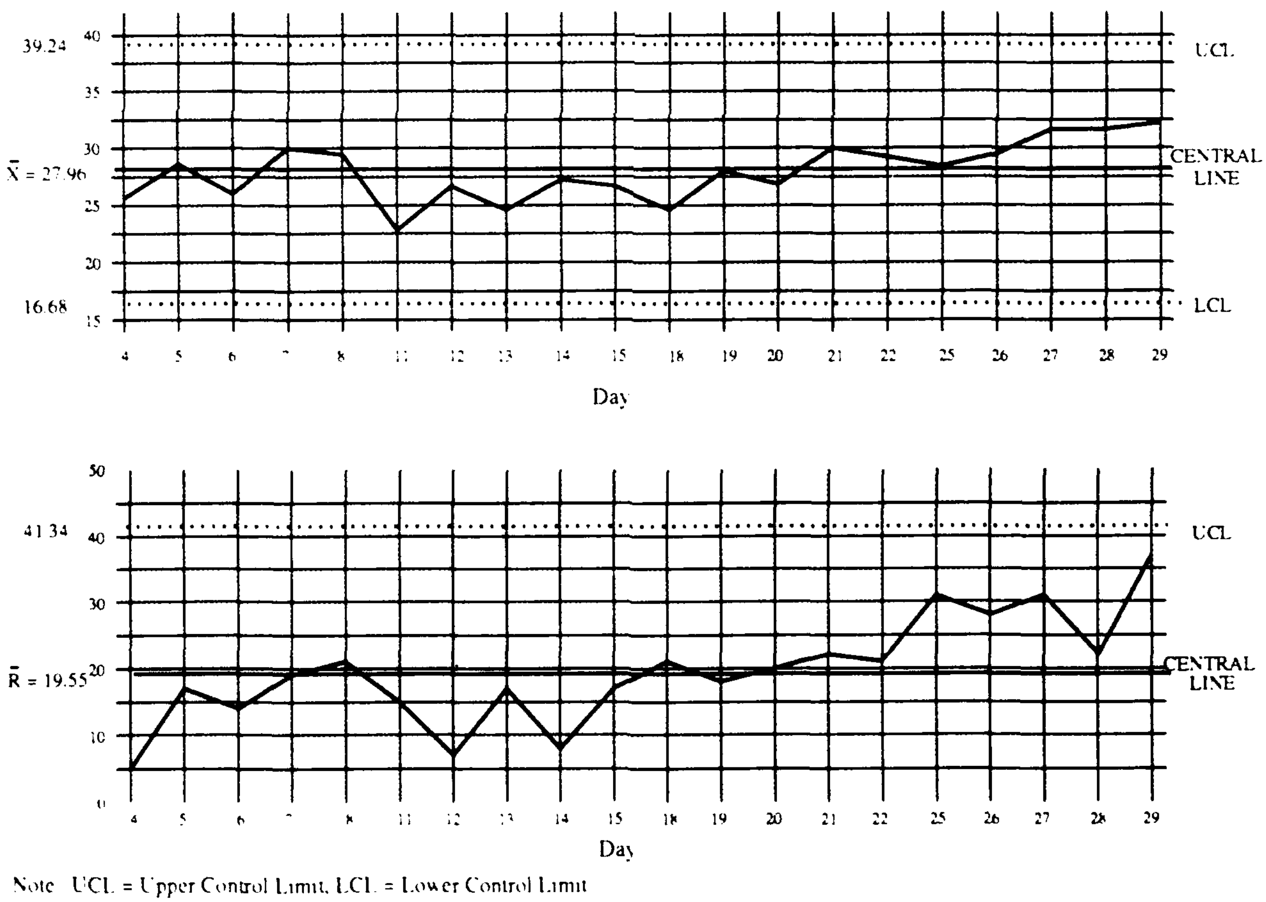

Figure 11. Control charts using hypothetical data.

Act Phase

At the conclusion of the Check phase, teams are supposed to select process variables believed to be major contributors to process quality and take action. During this exercise one major problem with the Block 0 process became obvious to the group. It was the lack of a design document. The group decided to investigate this part of the process more completely. Three groups were formed, each one looking at a slightly different aspect of the problem. After reviewing the importance of data collection (including hypothesis generation, types of data, sampling, and check sheet development), each group developed a data collection plan (Table 11). After approximately 2 months of data collection, the groups presented the results graphically and provided recommendations to the class for process improvement (Appendix).

Table 11

Summary of Things to Consider in Data Collection: What do We Need to Know?

1. Purpose of data collection.
2. What will be done with the data?
   a. Feedback
   b. Greater understanding
   c. Action
3. Types and sources of information that need to be gathered (i.e., frequencies, individual, group, other agencies, experts).
4. Methods of gathering data (i.e., interviews, checksheets, existing data) and the format and structure for each.
5. Sampling plan (i.e., when and how often data will be recorded and reported).
6. Who will collect the data?
7. How will the data be summarized and represented? Which graphic tool will be used?

LESSONS LEARNED

Perceptions of the Course by the Participants.

The participants reported that communication, especially interdepartmental, had improved as a result of the course and the group discussions. Participants from the different codes got an opportunity to see that the computer program generation process had the same kinds of problems regardless of the program platform or function. The development of a team involving the fleet user, the sponsors, and FCDSSA was often mentioned as a way to communicate accurately customer requirements and specifications.

The participants also reported that use of a real FCDSSA process facilitated their understanding of the uses and interpretation of the graphs and charts. They also believed they were more involved than they would have been had the process been hypothetical. It was difficult, however, to cover the activities required for structured problem solving and use of the tools in sufficient depth.

Perceptions of Course by the Instructors

Time was a problem. Process analysis and improvement can take many months, yet content and activities had to be covered in 2 weeks. A second problem concerned the development of process measures. The development of operational definitions is critical to this measurement task. Participants found that identifying measures and measurement itself to be very difficult. Another problem was the temptation to use existing data to answer questions. This can lead to different interpretations of the same data. Discussions surrounded the need and importance of developing unique measures to address specific hypotheses. It also appeared as though participants were skeptical about how the measures would be used as well as whether the measures developed would reflect process performance or their job performance.

The presentation sequence of the seven graphic tools here generally reflected their order and use in process improvement activities. However, this is not the only order in which they can be used. Tools can be used during any part of the PDCA cycle depending on the question the group wants answered.

Finally, the major impediment to the use of TQL and process improvement is not likely to be the nature of the process investigated or the difficulty of identifying measures, but rather the attitudes and practices of managers. Managers need to understand and agree that the TQL approach can be used to improve significantly the products and services of their organization.

RECOMMENDATIONS

1. Organizations interested in TQL should provide training to their employees on the graphic methods for quality improvement. The course should be taught by trained personnel and should meet on a weekly or biweekly basis for several months.

2. The graphic methods can be learned effectively by applying these tools to a real process that has significance to the organization. The ESC (or similar body of top managers) should be responsible for identifying the process.

3. The training should cover all of the graphic methods that an organization is likely to need. The training should demonstrate how these tools and techniques can be applied at several different phases of the PDCA cycle, and are not restricted to only a single phase.

4. Training should be extended over several months so that long term data can be collected. Control charts should be used to determine the stability of the process. If the process is not stable, an attempt should be made to stabilize it, if possible, before applying other charts and computations.

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APPENDIX

GROUP DATA COLLECTION PLANS

Group Data Collection Plans

Each group answered the items regarding data collection shown in Table 11. The summary provided focus and structure to the group discussions.

Group 1 investigated the various reasons why Trouble Reports (TRs) are written and the relative importance of each. TRs are written for a variety of reasons. A Program Performance Specification (PPS) may be too general, a Program Design Specification (PDS) may be lacking, and the relationship between PPS and the code may be incorrect. Hopefully the data will indicate whether designers and analysts need more detailed specifications and/or whether designer and programmer understand the requirements. The group felt that this part of the process was responsible for most of the TRs. The data consisted of expert judgments about approximately 100 TRs. Only TRs that were "closed" or "fixed" were used. The group developed and defined a classification scheme that categorized problems that possibly generated each TR. The categories included (1) high-level coding, (2) mistakes in the PPS, (3) using the wrong system operator manual (SOM), (4) mistakes in coding (5) using the wrong test procedure, (6) mistakes made by the tester, (7) requirements not specified, (8) mistakes in the Interface Design Specifications (IDS), (9) problems with hardware, (10) mismatch between coding and design, and (11) problems with configuration management. TRs were classified and a Pareto diagram developed to communicate the results.

The goals and objectives of the second group were similar to those of the first group. The group was interested in identifying the possible causes of coding problems. TRs identified by Group 1 as having coding problems were looked at by Group 2 in more detail. The categories they used for classifying TRs with coding problems included unclear PPS, error on the PPS, or incomplete PPS. Both groups hoped to document the need for a lower level-design document.

Groups 1 and 2 concluded from the Pareto chart (Figure A-1) that there was something wrong in the coding of the software. The first four categories on the Pareto chart involved coding mistakes due to lack of specification, mistakes in PPS, or mistake in the SOM. The groups hypothesized that problems in design documents were caused by inadequate documents and programming code. They recommended further study to determine the causes of inaccurate coding; correction would hopefully reduce the number of TRs produced. They recommended investigating low-level (machine) and high-level (compiler) programming codes.

Group 3 investigated whether excessive money, time, and personnel were being used analyzing invalid external TRs. They hoped to determine the price of nonconformance. The group's effort was described as exploratory in nature. They looked at existing TRs in the database that had a status code of Reject as Invalid, Fixed (RIF). They counted the number of TRs generated by the external agency relative to the total (Figure A-2). They concluded that the generation of external TRs wasn't as big a problem as they thought. They did report, however, that they thought the amount of time spent reviewing TRs was dependent on the level of management involved. The group felt that the information and what they learned from this effort would be useful to Fleet Combat Direction Systems Support Activity (FCDSSA) because it would help build communication between FCDSSA and the external agency.

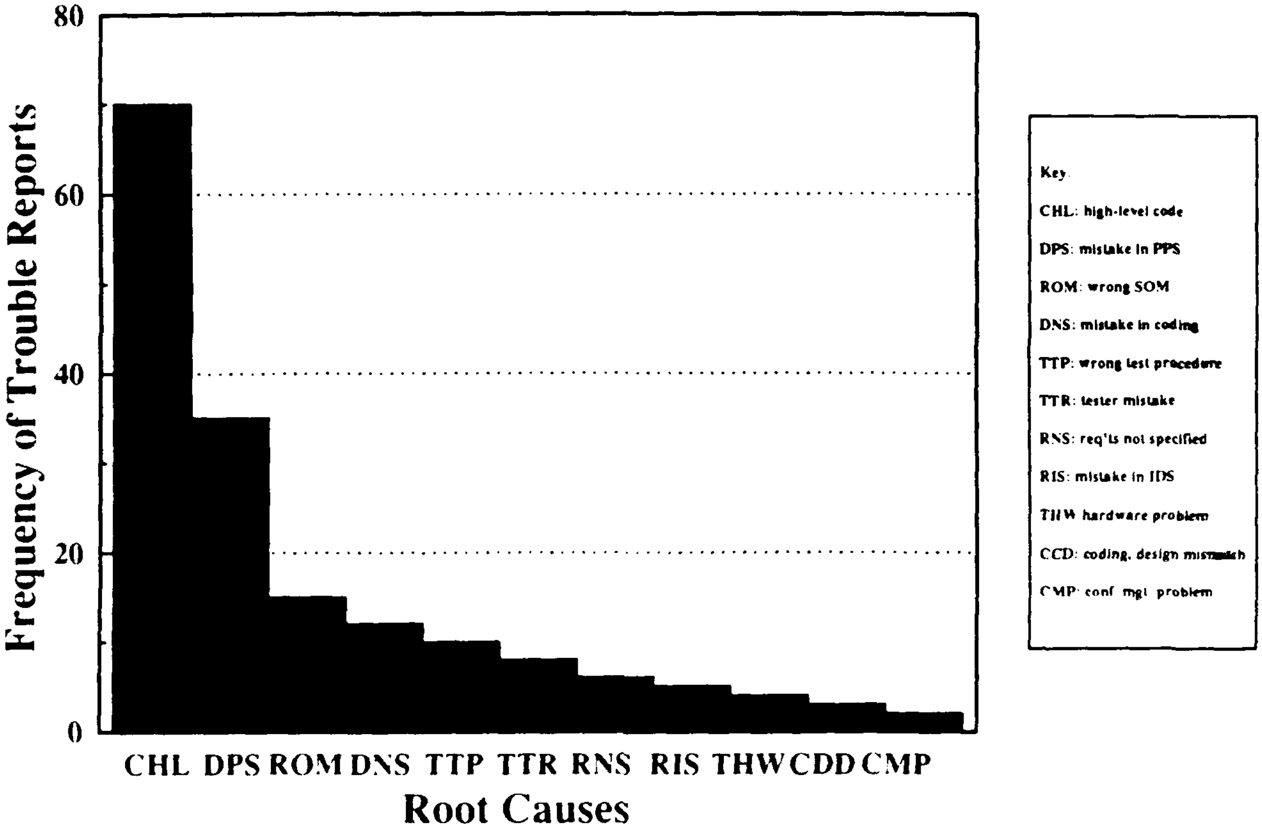

Figure A-1. Pareto chart of root causes of TRs.

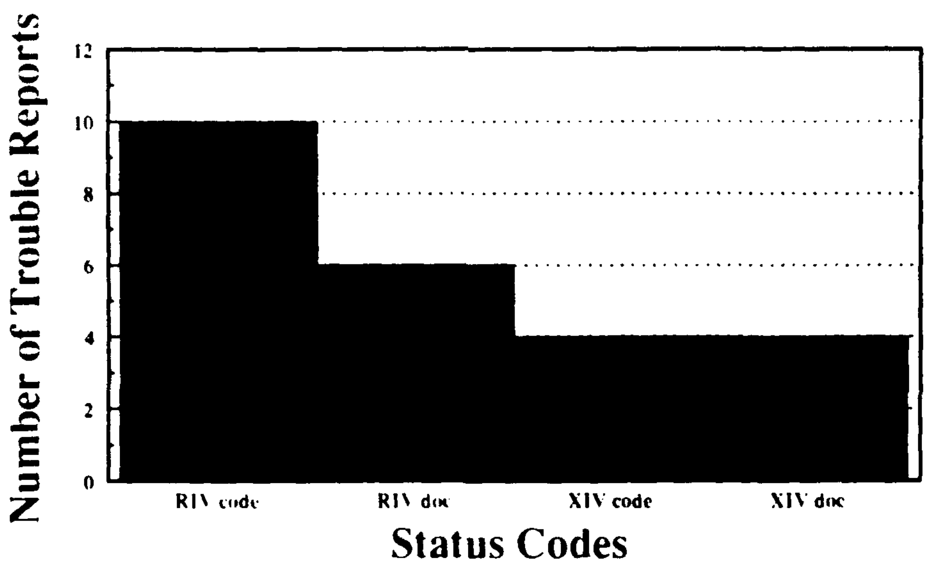

Figure A-2. Number of external TRs with status codes.

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