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16. Abstract <p>The stated objective of this project was to "provide research services for development of technology transfer for use of quality function deployment (QFD) in the shipbuilding industry." In support of this objective, UMTRI MSD (1) researched QFD teaching methods and applications in shipbuilding and other industries, (2) developed a short course/workshop for teaching QFD to the U.S. shipbuilding industry, (3) presented three QFD workshops for the U.S. shipbuilding industry, and (4) combined the Instructor's Manual, User's Manual, course overheads, and video tapes into a package that can be borrowed from the NSRP Documentation Center and used as the foundation for future presentations of QFD short courses/workshops.</p>					
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Appendix A

QFD User's Manual

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SHORT COURSE ON
QUALITY FUNCTION DEPLOYMENT
FOR THE
U.S. SHIPBUILDING INDUSTRY

Prepared By

The University of Michigan Transportation Research Institute,
Marine Systems Division

For The

NATIONAL SHIPBUILDING RESEARCH PROGRAM

Sponsor: U.S. Department of the Navy, Naval Surface
Warfare Center - Carderock Division.

Project Management: National Steel and Shipbuilding Co.

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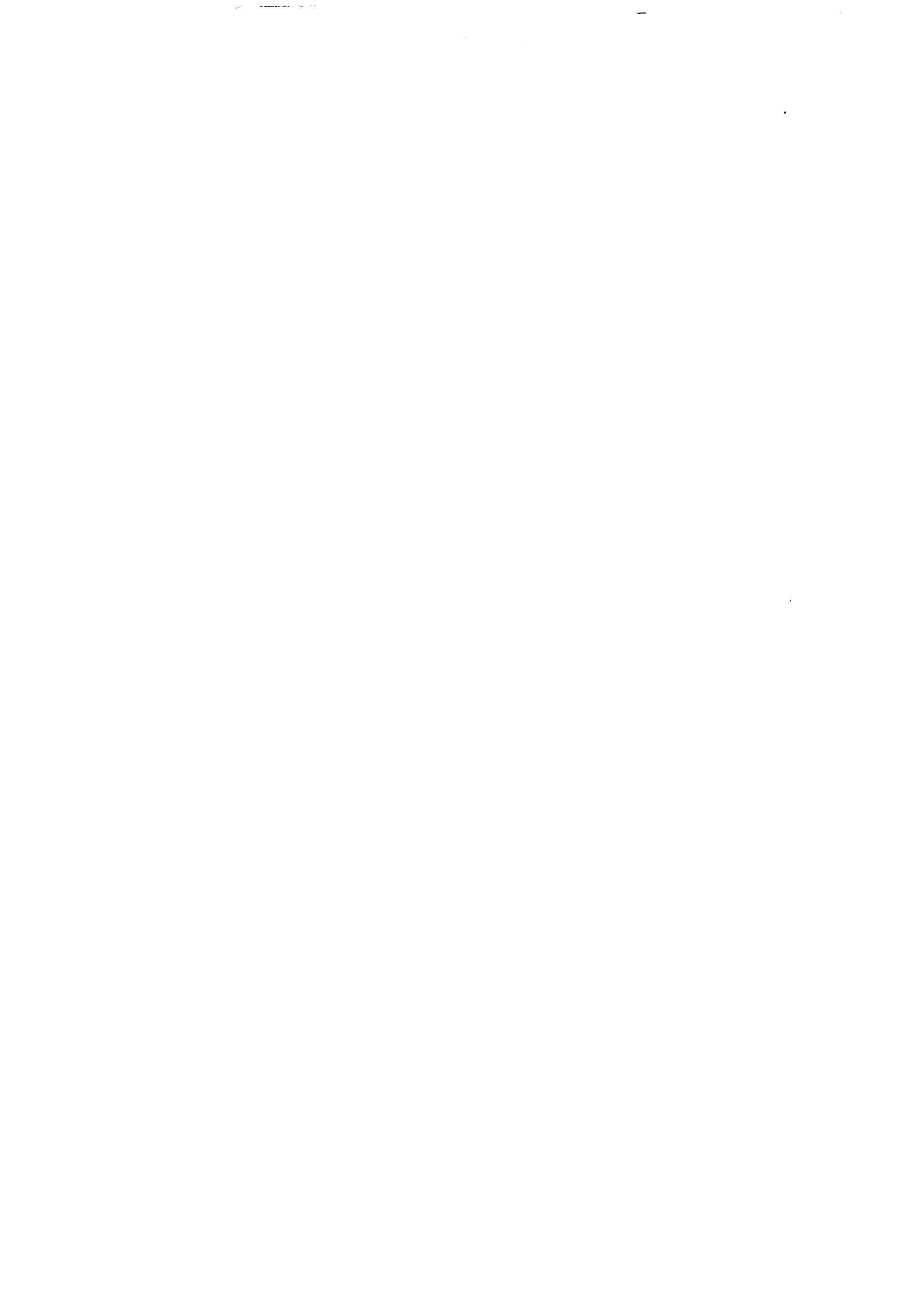


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EXECUTIVE SUMMARY

Quality Function Deployment (QFD) is a powerful tool for customer-driven product and process development and organizational planning. Nearly all world-class manufacturing and service companies are using some form of QFD as a key part of the Total Quality Management business philosophy.

This report, with the attached appendices, provides all of the textual course material and overhead slides necessary for the presentation of basic QFD training courses in the U.S. shipbuilding environment. Appendix A is the *QFD User's Manual* which serves as the basic text for the course, and as a general QFD reference guide. Appendix B is the *QFD Instructor's Manual* which is a copy of the *QFD User's Manual* with notes included for course instructors. Appendix C contains masters of all of the overhead slides associated with the QFD course, as called out in the *QFD Instructor's Manual*. This material is intended to be used in conjunction with five videotapes (NSRP Documentation Center reference: ED 91-95), produced by Technicomp, Inc., which can be rented from the National Shipbuilding Research Program (NSRP) Documentation Center at the University of Michigan (313-763-2465) or purchased directly from Technicomp.

This course material was developed specifically for the shipbuilding industry after extensive study of the QFD methodology as it has evolved and been applied in U.S. and foreign industries over the past two decades. Some of this course material has been borrowed with permission from other organizations involved with teaching QFD to industry, including GOAL/QPC, which facilitated an initial QFD workshop at Portsmouth Naval Shipyard in May 1991. As part of this research project, the QFD course developed for the NSRP was presented once in Ann Arbor, Michigan, and once in Baltimore, Maryland. The course has also been presented at the Naval Sea Systems Command (NAVSEA) under separate NAVSEA funding. Shipbuilding-related organizations that were represented at at least one of these courses were Avondale Industries, Bath Iron Works, Hopeman Brothers, Ingalls Shipbuilding, National Steel and Shipbuilding Company, Newport News Shipbuilding, Peterson Builders, MarAd, NAVSEA, Pearl Harbor Naval Shipyard, Portsmouth Naval Shipyard, U.S. Coast Guard Curtis Bay Shipyard, and the U.S. Department of Defense.

Any organization wishing to use this material to present a QFD course should utilize facilitators who are familiar with QFD and group dynamics, and who have thoroughly studied this course material and the associated videotapes. Any organization desiring assistance in organizing or facilitating a shipbuilding-related QFD course may wish to contact the University of Michigan Transportation Research Institute, Marine Systems Division, which developed this course material and facilitated the NSRP and NAVSEA courses associated with this project.

INTRODUCTION

As a result of U.S. shipbuilders' interest in Total Quality Management, the National Shipbuilding Research Program's Education and Training Panel, SP-9, initiated the Quality Function Deployment (QFD) project to facilitate research in QFD and to provide shipbuilding-related education in innovative, customer-driven product planning and development.

This QFD material was developed and associated workshops were presented for the NSRP by the University of Michigan Transportation Research Institute, Marine Systems Division. The background research was conducted by Professor Howard Bunch, Project Director, and Mr. Mark Spicknall, Senior Engineering Research Associate. The User's Manual, Instructor's Manual, and case studies were initially developed by Mr. Spicknall and graduate research assistant Mr. John Senger. As a result of feedback from workshop participants, the manuals and case studies were revised by Professor Bunch, Mr. Spicknall, research scientist Roger Horne, RAdm. U.S. Navy (ret.), and graduate research assistants Mr. David Amble and Mr. John Immink.

Some of the course material was developed directly from preexisting courses and texts on Quality Function Deployment. Sources of this preexisting material are:

Technicomp, Inc., 1111 Chester Avenue, Cleveland, OH 44114-3516, (800/735-4440). Videotapes from Technicomp have been used with permission as one of the major features of the NSRP QFD course. A copy of these tapes can be rented from the NSRP Documentation Center along with an Instructor's Manual and a User's Manual. It is illegal to duplicate these videotapes. Anyone interested in purchasing a copy of the videotapes should contact Technicomp, Inc.

GOAL/QPC, 13 Branch Street, Methuen, MA 01844 (508/685-3900). GOAL/QPC facilitated a QFD workshop at Portsmouth Naval Shipyard to help initiate this project, and to assist Portsmouth Naval Shipyard in its quality improvement efforts. Several references are made in this manual to GOAL/QPC's "Matrix of Matrices" approach to QFD. Additionally, sections of the appendices are excerpts from the book, Better Design in Half the Time: Implementing Quality Function Deployment, by Bob King and published by GOAL/QPC in 1989.

Florida Power and Light (FP&L) - Quality Improvement Department,
P.O. Box 14000, Juno Beach, FL 33408-0420, (305/552-4421). The
primary project researchers attended a workshop presented by FP&L.

Prof. Yoji Akao, Tamagawa University, Japan. Prof. Akao's
textbook, Quality Function Deployment, Integrating Customer
Requirements Into Product Design, Productivity Press, 1990, was an
important resource.

American Supplier Institute, Incorporated, Six Parklane Boulevard,
Suite 411, Dearborn, MI 48216 (313/336-8877). The American Supplier
Institute (ASI) has been conducting QFD workshops for over ten years,
and is credited with introducing QFD to Ford Motor Company.

When material was used from these sources without modification in the NSRP
manuals, overheads, and within the actual courses, permission was obtained from the
appropriate sources.

These manuals and overheads, along with the associated videotapes, are intended to
provide any shipbuilding-related organization with the tools necessary to conduct a course in
the fundamentals of Quality Function Deployment. Several ship design- and construction-
related case studies have been included for course participants or individuals to use in
developing their QFD skills within a shipbuilding context. The following "Project
Overview" provides a detailed description of the QFD course material.

Acknowledgments

The project team would like to thank Capt. Jay Smith, Mr. David McCarthy, Mr.
Gene Foster, and Portsmouth Naval Shipyard (PNS) for hosting a QFD workshop to help
initiate this project. Capt. Smith has been particularly helpful as a volunteer consultant to the
project team. The team would also like to thank Dr. Jim Naughton of GOAL/QPC for
facilitating the PNS workshop. The team would like to thank Mr. Steve Maguire of
Avondale Industries, Mr. Jeff McCann and Mr. Mark Lasher of Bath Iron Works, Mr. Tom
Rakish of Ingalls Shipbuilding, Mr. Thomas Thompson of National Steel and Shipbuilding,
Mr. Leland Nelson of Peterson Builders, and Mr. Gerry Damon of Pearl Harbor Naval
Shipyard for contributing to the project as representatives of the shipbuilding industry at the
initial workshop.

PROJECT OVERVIEW

Definition of Quality Function Deployment

QFD is a disciplined planning process that facilitates the identification and deployment of customer wants and needs throughout a company as a basis for product planning, development, and implementation. QFD provides a system in which the voice of the customer drives product planning, product design, process planning, process control planning, production, sales, and service.

QFD is a key element of the Total Quality Management process, and is used in some form by virtually all world-class companies, including many successful commercial shipbuilders. In fact, QFD was first developed and used as a formal process at Mitsubishi's Kobe shipyard in 1972. QFD is credited with:

- enhancing internal and external communications,
- improving quality,
- increasing customer satisfaction,
- reducing product development time,
- lowering new product start-up costs,
- reducing the number of design changes,
- reducing warranty claims,
- fostering cross-function team building,
- facilitating simultaneous product and process design,
- improving design for production,
- allowing lower pricing as a result of lower development costs,
- removing bottlenecks in product development/implementation,
- building a database for future product development,
- providing a means of evaluating competition, and
- identifying key areas in product development where resources can be focused to gain competitive advantages.

General Format of the NSRP QFD Course

After attending other QFD courses and reviewing all available QFD references and texts, the project team decided on the following presentation format:

- (1) General overview of the QFD process and its potential benefits.
- (2) Detailed presentation of the Product Planning Matrix, or "House of Quality," including demonstration of the basic tools used to organize information for developing a matrix diagram.

- (3) Basic group case study exercise on developing a Product Planning Matrix (with customer requirements already provided), including discussion of group dynamics and consensus decision making.
- (4) Detailed presentation on obtaining and interpreting "the voice of the customer."
- (5) Detailed case study exercises including interpreting the voice of the customer, developing and organizing customer requirements, and developing and interpreting the Product Planning Matrix.
- (6) Detailed presentation of QFD project evolution and other QFD matrices.
- (7) Continuation of detailed case study exercises with creation and analysis of other QFD matrices.
- (8) Review of QFD fundamentals and other sources of QFD information.

Prior to developing this course's format, project team members and shipyard representatives attended other courses and workshops where the QFD process was presented chronologically; that is, methods of obtaining and interpreting the voice of the customer were presented first, followed by explanations of the Product Planning Matrix and other matrices. Project team members and shipyard representatives who attended some of these courses agreed that, without an overview of QFD and the Product Planning Matrix presented first, these courses lacked direction. Therefore, the NSRP course has been organized to provide an overview of the entire QFD process and of the Product Planning Matrix before presentation of material on obtaining and interpreting the voice of the customer. This format has proven to be successful, as participants in the QFD courses presented as part of this project have demonstrated a good general understanding of QFD by the end of the first day of the course.

Group Dynamics And The QFD Process

Group dynamics play an important role in the potential success of the QFD process. The process usually involves people with diverse backgrounds from many different areas and levels of an organization. When QFD is first being tried by an organization, it is likely that many of the participants will be unfamiliar with each other and with other areas of the organization. It is absolutely critical that these participants overcome any parochialism that might exist so that they can work effectively as a team. Decisions made by team consensus during the QFD process are more likely to result in meaningful and useful organizational action. While there is no formal instruction provided in this course in the areas of group dynamics and consensus decision-making, there are some suggestions for managing group

dynamics provided in the course manuals at the beginning of Section V, Case Studies. For first-time QFD implementation by an organization, it is recommended that facilitators be utilized who are familiar with team-building and consensus decision-making, as well as with QFD.

CONCLUSIONS

Quality Function Deployment has proven to be a valuable product planning and cross-functional management tool for world-class companies around the world. It is one of the key elements of Total Quality Management. QFD's primary strengths are that (1) it causes an organization to focus on customer requirements, needs, expectations, and desires as the basis for its products, services, and actions, and (2) it provides a mechanism that helps diverse interests within an organization communicate effectively. These strengths, in turn, facilitate teamwork and concurrent development of products and services that meet or exceed customer expectations.

It is likely that U.S. shipbuilders will have to use some form of QFD in order to compete successfully in the commercial shipbuilding market. The course material presented with this report, along with the videotapes available from the NSRP Documentation Center, can provide U.S. shipyards with the basic foundation required to begin using QFD.

QUALITY FUNCTION DEPLOYMENT

User's Manual

The National Shipbuilding Research Program

QUALITY FUNCTION DEPLOYMENT

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QUALITY FUNCTION DEPLOYMENT

User's Manual

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QUALITY FUNCTION DEPLOYMENT

Foreword

The Quality Function Deployment (QFD) project was initiated by the National Shipbuilding Research Program (NSRP) to research and demonstrate methods of customer-driven planning for total quality shipyard operations.

This QFD material was developed, and associated workshops were presented, for the NSRP by the University of Michigan Transportation Research Institute, Marine Systems Division. The background research was conducted by Prof. Howard Bunch, NAVSEA Professor of Ship Production Science and project director, and Mr. Mark Spicknall, Senior Engineering Research Associate. The User's Manual, Instructor's Manual, and case studies were initially developed by Mr. Spicknall and graduate research assistant Mr. John Senger. As a result of feedback from workshop participants, the manuals and case studies were later revised by Prof. Bunch, Mr. Spicknall, research scientist Roger Horne, RAdm. U.S. Navy (ret.), and graduate research assistants Mr. David Amble and Mr. John Immink.

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Florida Power and Light (FP&L) - Quality Improvement Department, P.O. Box 14000, Juno Beach, FL 33408-0420, 305-552-4421. The primary project researchers attended an excellent TQM workshop presented by FP&L. FP&L's actual "House of Quality" provided a good reference for developing this material.

When material was used without modification, permission was obtained from the appropriate sources.

SECTION I: BASIC CONCEPTS OF QUALITY FUNCTION DEPLOYMENT

I. BASIC CONCEPTS OF QUALITY FUNCTION DEPLOYMENT

Definition of Quality Function Deployment (QFD)

QFD is a disciplined planning process that facilitates the identification and deployment of customer wants and needs throughout a company as a basis for product planning, development, and implementation. QFD provides a system in which the voice of the customer drives product planning, product design, process planning, process control planning, production, sales, and service.

In the QFD context, the "customer" is anyone who uses your goods or services: a ship owner who uses a ship that you build, an engineer who uses your ship design, a mechanic who uses your work instructions, and the purchasing department who uses your material specifications could all be your customers. QFD can be used to address the needs of any of these external or internal customers.

In the QFD context, the word "quality" has a different meaning than the traditional definition, "conformance to requirements." In the parlance of QFD, the word "quality" refers to those attributes that customers want or need in the product or service of a supplier. These attributes are sometimes referred to as "customer requirements," "demanded quality," or "quality requirements." Using the QFD methodology these "customer requirements" can be deployed throughout the supplier's organization and used as the foundation for defining the products and, necessarily, the internal functions of that organization.

The History Of QFD

The QFD methodology was conceived and first used as a formal discipline at Kobe Shipyard of Mitsubishi Heavy Industries in 1972. Since that time QFD has been adopted by most world-class product and service suppliers as part of the Total Quality Management (TQM) philosophy. Some U.S. companies that have made QFD an integral part of doing business are Motorola, Ford, Rockwell International, and IBM.

QFD Benefits

There is overwhelming evidence that major improvements in products, services, and operations result from the use of QFD. Below is a list of benefits reported by organizations that have utilized QFD.

- Enhances internal and external communications
- Improves quality
- Increases customer satisfaction
- Reduces product development time by 30-50%
- Lowers start-up costs by 20-60%
- Reduces the number of design changes by 30-50%
- Reduces warranty claims by 20-50%
- Fosters cross-function team building
- Facilitates simultaneous product and process design
- Improves design for production
- Allows lower pricing because of lower development costs
- Removes bottlenecks in product development/implementation
- Builds a database for future product development
- Provides a means of evaluating your competition
- Identifies key areas in product development where time and effort can be focused to gain competitive advantages

QFD Terminology

QFD texts from different sources sometimes use different terminology to represent equivalent concepts and tools. Following is a list of some common equivalent terminology that might be encountered in QFD material. In each instance, the first term presented is the term used in this text.

- Customer Requirements: quality requirements, demanded quality, required quality
- House of Quality: product planning matrix, A-1 Matrix
- Product/Service Characteristics: technical requirements, quality elements, quality characteristics, quality items
- Interim Product/Part Characteristics: part characteristics, mechanisms, unit parts, systems, sub-systems, parts, components, raw material
- Process Control Characteristics: process control methods

The QFD Process

The QFD process that will be the focus of this course is illustrated in Figure 1. Following are brief descriptions of individual process steps.

Defining a QFD Project

QFD is best applied to a specific need, i.e. to a specific area for which improvement or breakthrough is required or desired. In this regard, it is best to define a QFD project in the context of

- one customer or market segment,
- one product or service area where improvement is desired, and
- one point in time.

For example, a commercial shipbuilder may have identified that the buyers of new very large crude oil carriers (VLCCs) want significant reductions in fuel costs without a sacrifice in

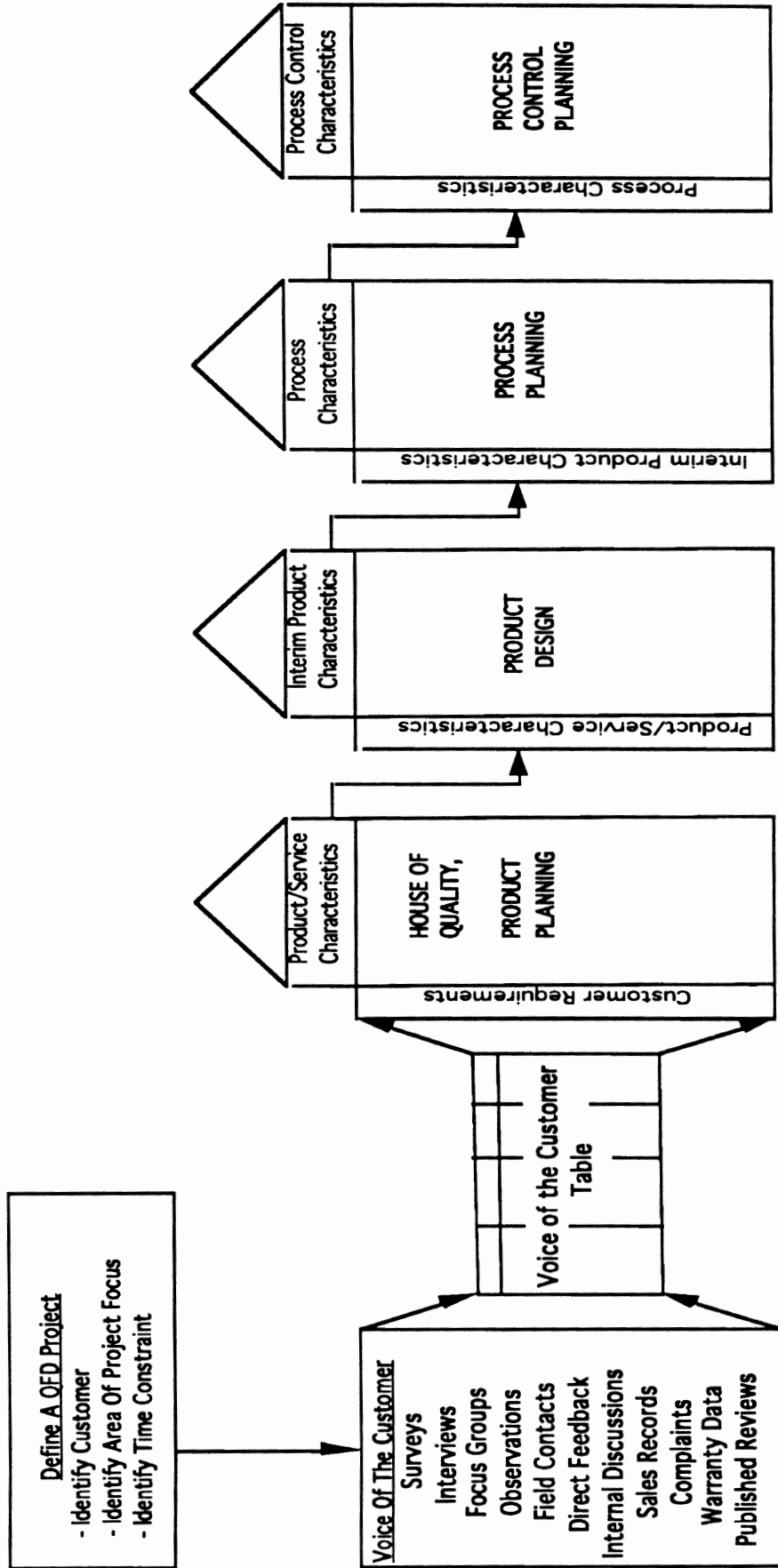


Figure 1. The Four-Matrix QFD Process.

performance by 1994. The identification of a specific customer, a specific product need, and a specific time will allow this shipbuilder to carry out a well focused QFD project. QFD can be used for the development or improvement of any type of product or service, including manufacturing, construction, software development, or customer service. for external or internal customers.

The Voice of the Customer

The voice of the customer is the foundation of QFD. The customer's voice represents the wants, needs, desires, and requirements that are deployed throughout an organization to be used as the basis for product development and implementation. The voice of the customer is actually a conglomeration of many customer voices gathered from questionnaires, surveys, interviews, claims information, observations, etc., and represents only an approximation of the customers' requirements. Obviously, this approximation will be more accurate and complete if a large quantity of quality information is available and organized in a rational manner. A tool called the Voice of the Customer Table (VOCT) is used to organize this information into specific, positive, singular customer requirements. The detailed examination and organization of the voice of the customer will be the subject of Section III.

The "House of Quality", Product Planning Matrix, or A-1 Matrix

The "House of Quality," Product Planning Matrix, or A-1 Matrix shown in Figure 2, is used to begin to translate the customer's requirements into the technical language of the supplier's organization, to identify relationships between customer requirements and the product/service characteristics that can be affected by the supplier, to prioritize these customer requirements and potential supplier action areas, and to identify the relative strengths and weakness of alternative products/competitors. The detailed development of the "House of Quality" will be the subject of Section II.

Further Product Development and Implementation

From the "House of Quality" a number of other matrices can be developed for various purposes. Bob King of GOAL/QPC developed the "Matrix of Matrices" in Figure 3, which consists of an additional 29 matrices that can be used for everything from product failure mode analysis to prioritizing new product concepts relative to customer requirements. This course will focus on a simplified four-matrix QFD approach shown in Figure 1.

It is important to note that QFD is completely flexible with regard to the matrices that are appropriate for a specific project. QFD users may even develop matrices that are not a part of the approach shown in Figure 1 or part of the "Matrix of Matrices" if there is a need.

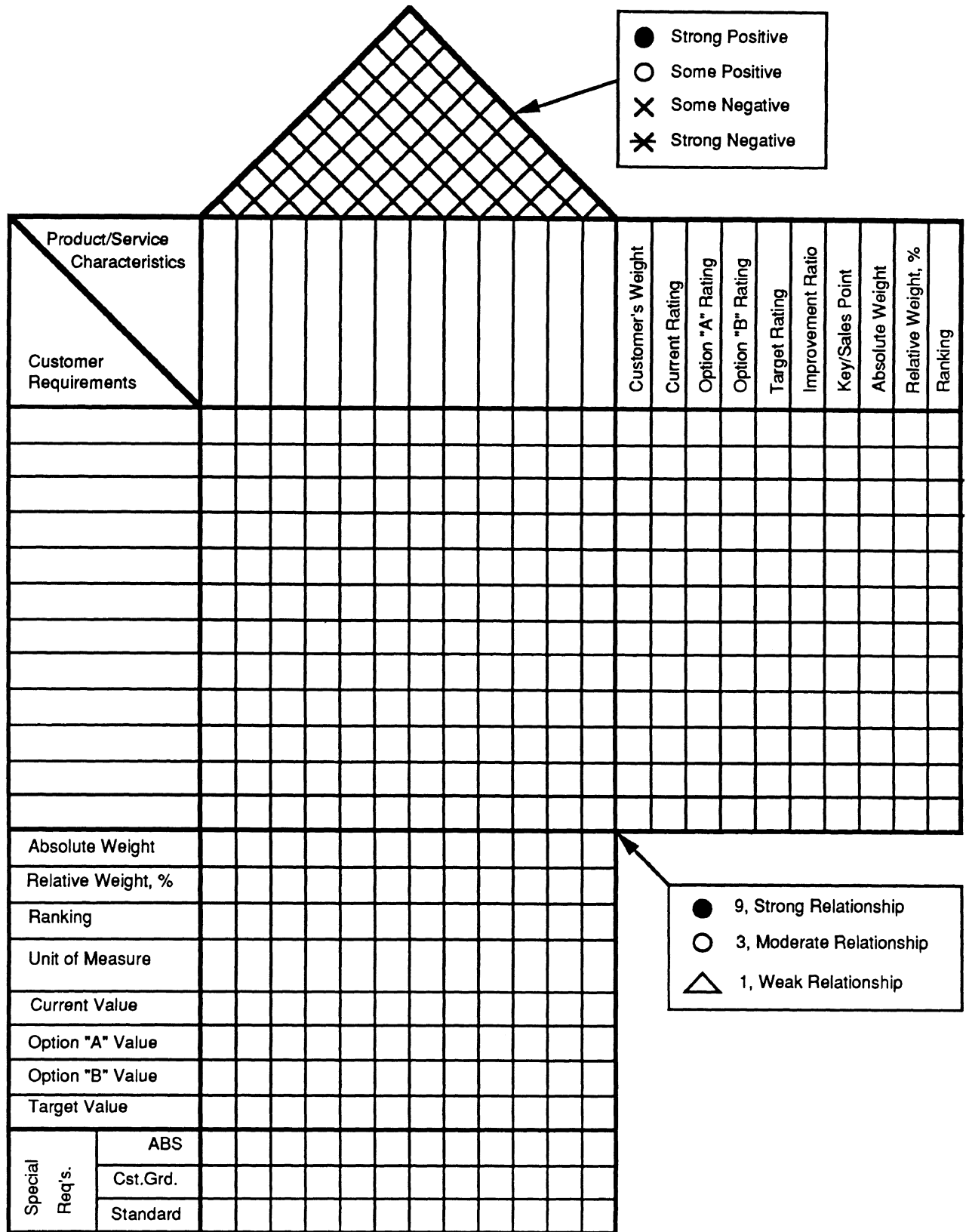
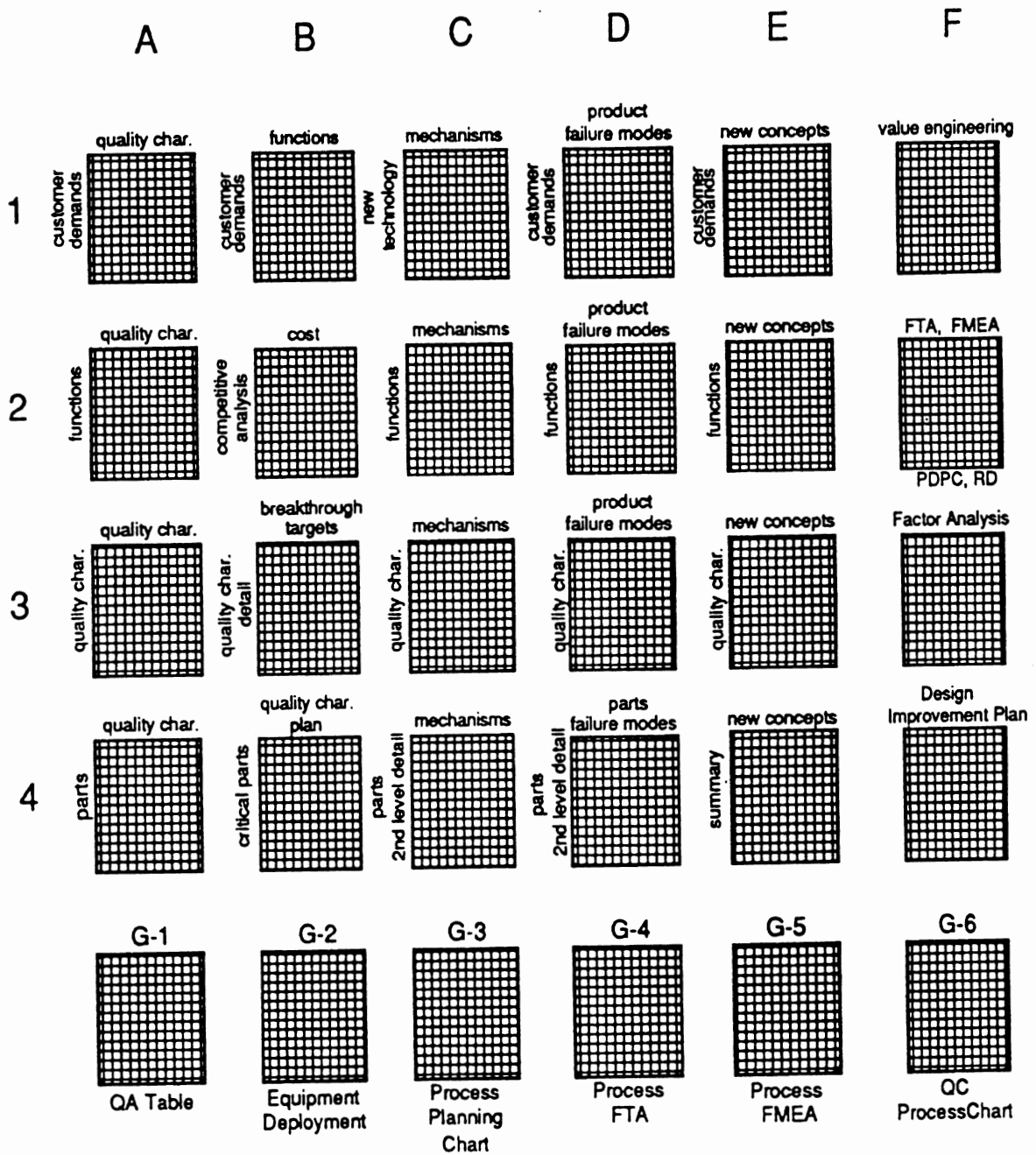


Figure 2. The House Of Quality/Product Planning Matrix.



Source: GOAL/QPC

Figure 3. The Matrix of Matrices.

Requirements For QFD Success

1. Management commitment for at least a QFD pilot project is a minimum requirement.
2. Active support and participation of management is ideal.
3. Project team diversity is essential. The team may include members from:

- Strategic Planning
- Marketing
- Design/Engineering
- Process Engineering
- Production Engineering
- Production
- Quality Assurance

Depending on the type of QFD project, the team might also include:

- Purchasing
- Distribution
- Accounting
- Finance
- Human Resources
- Suppliers
- Customers

4. Project team members must have a basic understanding of QFD and must be committed to the QFD process.

SECTION II: THE HOUSE OF QUALITY

II. THE HOUSE OF QUALITY

Initial Tools

Three of TQM's "Seven Management Tools" (see Appendix C) are used to help create the "House of Quality" and many of the other QFD matrices. These tools are the affinity diagram, the tree diagram, and the matrix diagram. The application of affinity diagrams and tree diagrams to QFD is discussed below.

The Affinity Diagram

As the name implies, the affinity diagram is used to collect ideas such as customer requirements or related product characteristics developed from group brainstorming into similar groups. Each group is then given a heading to describe or summarize its contents. See Figure 4.

Example: Your customer is the shipyard mechanic. This is a list of your customer's requirements for a shipbuilding work package:

- Bill of material
- Any special tools required
- Complete work sketches
- Definition of global reference lines to be used
- All material for production of the interim product
- All necessary production control documentation
- Accurate pieces
- Accurate list of material
- All pieces with proper ID
- All necessary inspection documentation
- Accurate work instructions
- Proper reference lines or marks on all pieces
- Work sketches without unneeded information

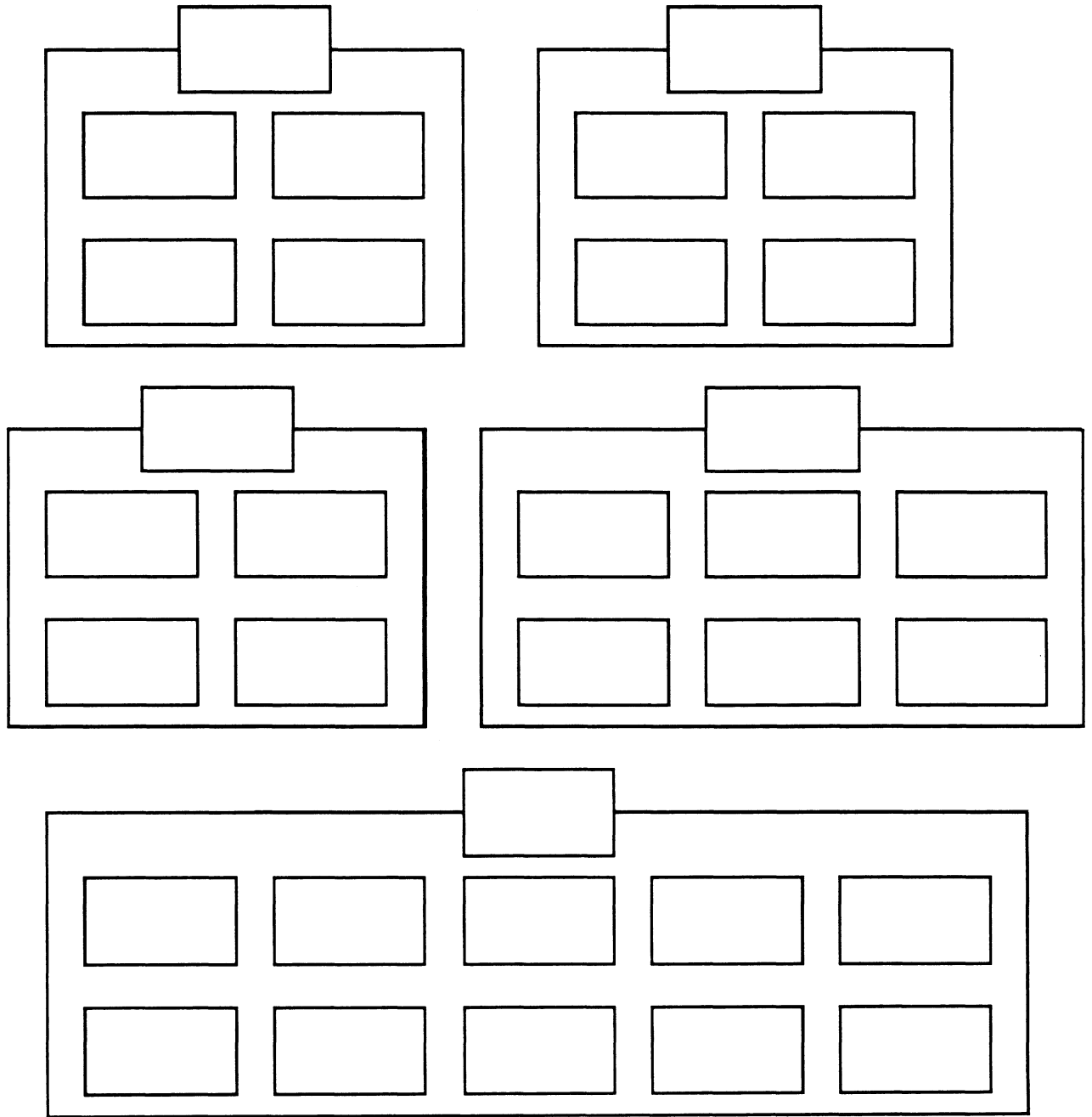


Figure 4. Affinity Diagram.

These customer requirements might be grouped in an affinity diagram as follows:

- Correct Parts
 - All material for production of the interim product
 - Accurate pieces
 - All pieces with proper ID
 - Proper reference lines or marks on all pieces
- Correct Bill of Material
 - Accurate list of material
 - Any special tools required
- Correct Instructions and Sketches
 - Complete work sketches
 - Definition of global reference lines to be used
 - Accurate work instructions
 - Work sketches without unneeded information
- Correct Work Documentation
 - All necessary production control documentation
 - All necessary inspection documentation
- Correct Tools
 - Any special tools required

Notice that some customer requirements fall into more than one group. This is possible and acceptable. What is important is that the requirements are organized into a framework that allows them to be addressed logically.

Less Detailed,
More Important - - - - - More Detailed,
Less Important

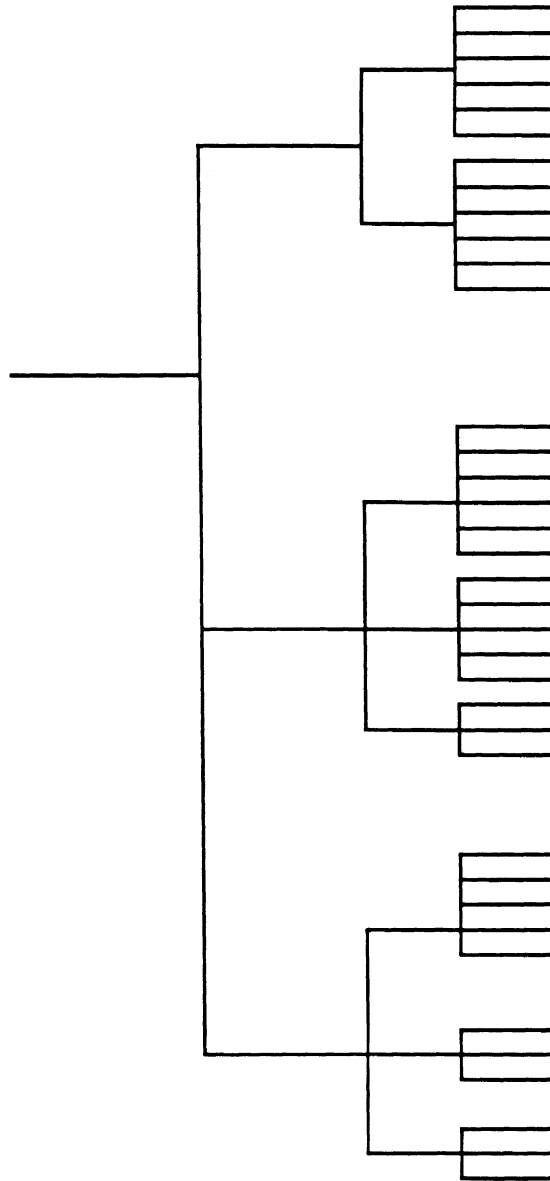


Figure 5. Tree Diagram.

Once the tree diagram is complete, a particular level of detail can be selected for use along an axis of a QFD matrix. Figure 6 illustrates how tree diagrams are used in the creation of a QFD matrix.

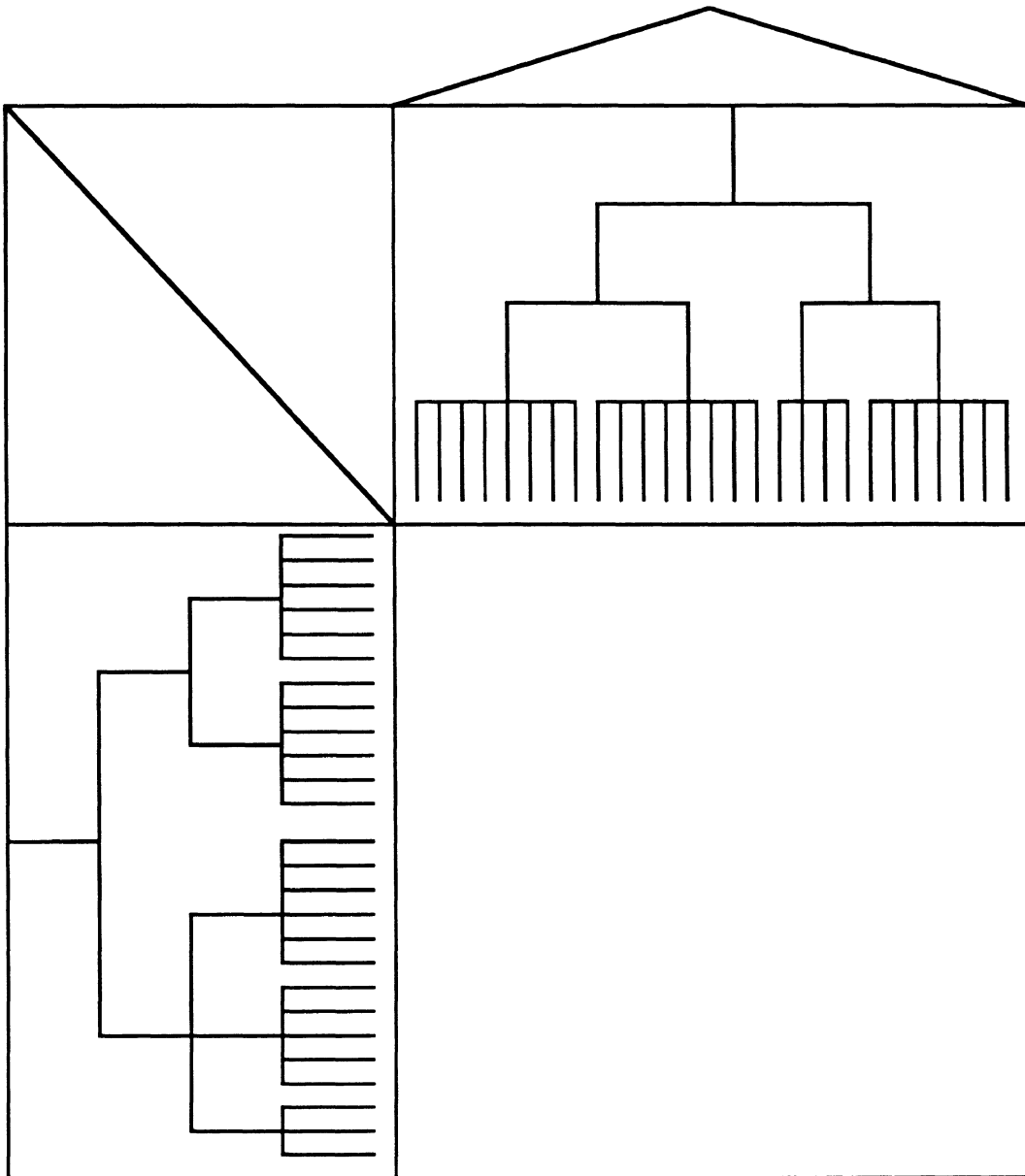


Figure 6. Tree Diagrams Related To A QFD Matrix.

The House Of Quality, Product Planning Matrix, or A-1 Matrix

Figure 7 shows a product planning reference matrix with sections labeled from **A** to **W**. Following are detailed descriptions of each section of the House Of Quality.

A- Customer Requirements, The Customer's World

1. Surveys, observations, direct feedback, brainstorming, etc. are used to identify customer wants and needs.
2. Customer requirements are singular, positive statements of need. Customer requirements must not include numbers or words that refer to areas that are addressed by other QFD matrices, such as function, interim product characteristics, or process characteristics.
3. An affinity diagram is used to group these wants and needs into logical categories.
4. A tree diagram is used to establish the relationships between, and importance of, customer wants and needs, and to help assure that the list of wants and needs is complete.
5. A particular level of detail from the tree diagram is then chosen for representation of the customer requirements in the product planning matrix.

B- Product/Service Characteristics, The Supplier's World

1. Product/service characteristics are the measurable and controllable things the supplier can affect to address customer requirements. Product characteristics are developed by brainstorming for each customer requirement: "How can we, the supplier, address this customer need?" Or, more specifically: "What things about our product (or service) can we, the supplier, affect to address this specific customer need?"
2. Product/service characteristics must not include references to customer requirements or to areas that are addressed by other QFD matrices.
3. An affinity diagram is used to group the things the supplier can affect into logical categories.

4. A tree diagram is used to establish the relationships among, and importance of, these things the supplier can affect, and to help assure that the list is complete.
5. A particular level of detail from the tree diagram is then chosen for representation of the product/service characteristics in the product planning matrix.

C- Relationship Matrix

1. The relationship matrix is used to identify how strongly specific product/service characteristics affect or control individual customer requirements.
2. Different symbols are used to represent the strengths of relationships:
 - =strong relationship=9
 - O=moderate relationship=3
 - Δ=weak relationship=1
 - blank=no relationship=0
3. The numerical values associated with the different types of relationships are used to calculate the absolute weights of product/service characteristics (see **N**).

D - Customer's Weight

1. The customer's weight is a number between 1 and 5, determined by the project team to reflect the relative importance of each customer requirement to the customer. This judgment is based on "voice of the customer" information.

1=not very important to customer; 5=extremely important to customer

E, F, G- Ratings of Ability to Meet Customer Requirements

1. **E** is a set of ratings from 1 to 5 that reflect how well the current product/service meets each customer requirement.
2. **F** and **G** are ratings from 1 to 5 that reflect how alternative product/service options, perhaps those of competitors, currently meet customer requirements. These other products/services must be known well enough to allow objective rating.

1= does not meet requirement very well; 5=meets requirement extremely well

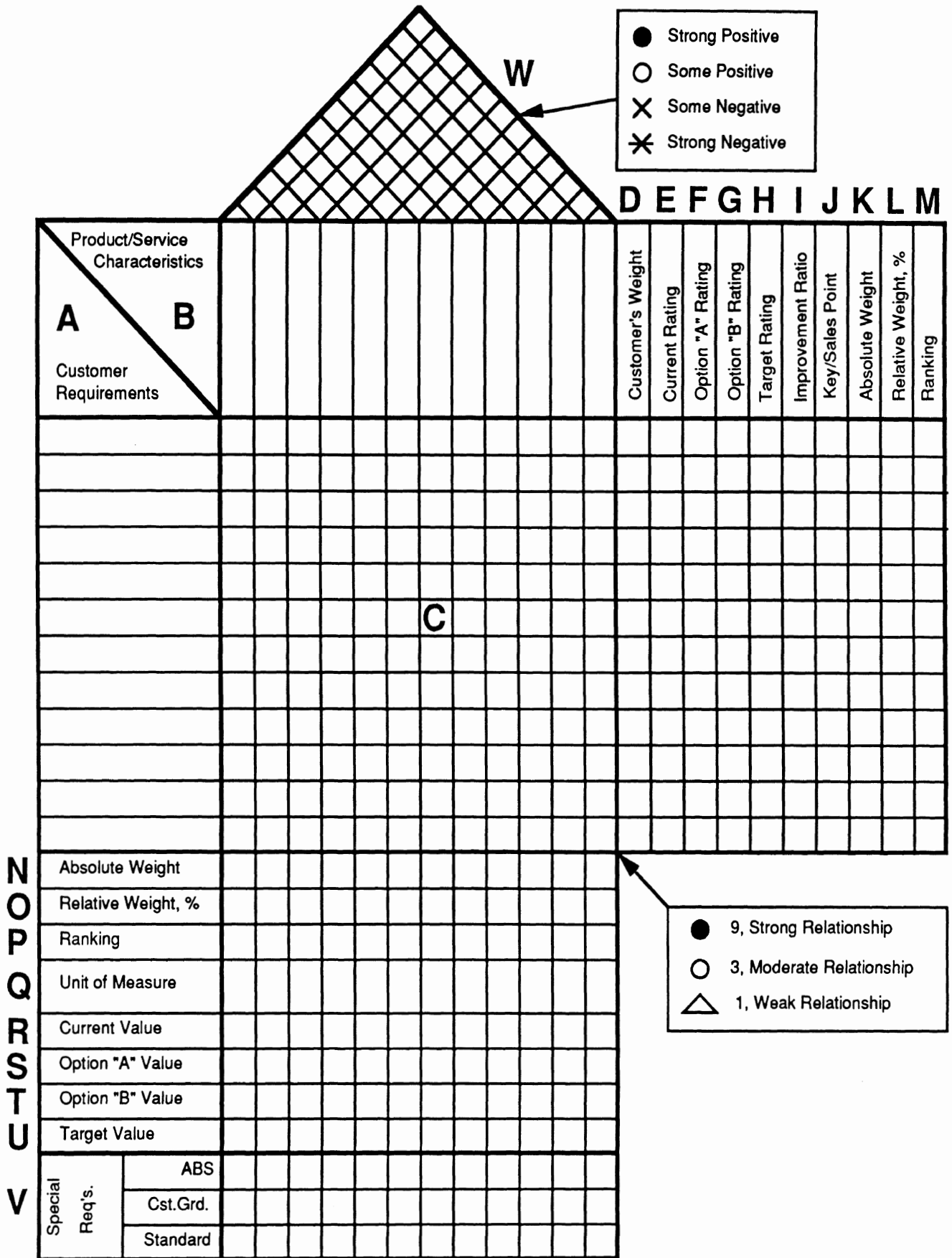


Figure 7. House Of Quality/ Product Planning Reference Matrix.

H - Target Rating

1. Target ratings are from 1 to 5 and reflect the goals of the supplier organization for satisfying each customer requirement.

I - Improvement Ratio

1. The improvement ratio for each customer requirement reflects what percent change is required over the current rating, **E**.
2. This ratio is calculated for each customer requirement as target rating divided by current rating, **H/E**.

J - Key or Sales Point

1. Key points or sales points identify those customer requirements that could have a significant impact on customer satisfaction and sales.
2. Customer requirements with a high customer weight are often key or sales points. Also, customer requirements that are considered new or exciting could be key or sales points.
3. Major key or sales points are given a value of 1.5. Minor key or sales points are given a value of 1.2. All other customer requirements are given a key or sales value of 1.

K - Absolute Weight of Customer Requirements

1. This absolute weight quantifies the overall importance of each customer requirement.
2. $K = D \text{ (Customer's Weight)} * I \text{ (Improvement Ratio)} * J \text{ (Sales Point)}$

L - Relative Weight of Customer Requirements

1. The relative weight of each customer requirement expresses the absolute weight of each customer requirement relative to the total absolute weights of all customer requirements in terms of a percentage.
2. $L = 100 * K \text{ (Absolute Weight)} / \sum K \text{ (Sum Of All Absolute Weights)}$

M - Ranking of Customer Requirements

1. Rankings simply present the order of importance of the customer requirements based upon their relative weights.

N - Absolute Weight of Product/Service Characteristics

1. This absolute weight quantifies the overall importance of each product/service characteristic by accounting for the relationships between each individual product/service characteristic and all customer requirements.
2. $N = \sum [C \text{ (Relationship Matrix Score)} * L \text{ (Relative Weight)}]$

O - Relative Weight of Product/Service Characteristics

1. The relative weight of each product/service characteristic expresses the absolute weight of each product/service characteristic relative to the total absolute weights of the other product/service characteristics in terms of a percentage.
2. $O = 100 * N \text{ (Absolute Weight)} / \sum N \text{ (Sum Of All Absolute Weights)}$

P - Ranking of Product/Service Characteristics

1. Rankings simply present the order of importance of the product/service characteristics based upon their relative weights.

Q - Unit Of Measure

1. If a specific product/service characteristic has a unit of measure, that unit of measure is shown in this field. Example: product characteristic "length" could have a unit of measure "meters."
2. Nondimensional measures, or indices, can also be used to represent some specific types of product/service characteristics.

R - Current Value

1. If the current product/service has particular values for specific product/service characteristics, these values are shown in these fields.

S, T - Option Values

1. These values show the product/service characteristic values of alternative products/services options, perhaps those of competitors.

U - Target Value

1. Target values reflect the goals of the supplier organization for each important product/services characteristic.
2. Target values can be based on what competitors are achieving, on experimentation, on research, etc.
3. Target values must agree with the chosen units of measure. They must be measurable, and project team members must agree on how target values will be measured.

V - Special Requirements

1. Special requirements are those things that must be considered during product planning that represent the requirements of customers other than the primary customer identified, such as regulatory agencies and the organization itself.
2. Special requirements are identified at the product planning stage to assure that they are addressed throughout the entire product development process.

W - Correlation Matrix

1. The correlation matrix is used to identify product/service characteristics that are related in synergistic or conflicting ways. A synergistic relationship means that, as one product/service characteristic is moved toward its desired target, it forces another product/service characteristic to also move toward its target. A conflicting relationship means that, as one product/service characteristic is moved toward its desired target, it forces another product/service characteristic to move away from its target.
2. Conflicting relationships between product/service characteristics identify that design and development compromises will be required in these areas.

3. Different symbols are used to represent the strengths of relationships.

●=strong synergistic relationship

○=moderate synergistic relationship

X=moderate conflicting relationship

*=strong conflicting relationship

blank= no relationship

Analysis of a Product Planning Matrix

Once a product planning matrix has been completed, it is important to check certain attributes of the matrix for completeness, level of detail, and consistency.

1. A blank row in the relationship matrix may indicate that a product/service characteristic has not been identified to address that specific customer requirement.
2. A blank column in the relationship matrix may indicate that an unimportant product/service characteristic has been identified, or that a particular customer requirement has been inadvertently ignored.
3. If an important customer requirement has no strong relationship with any product/service characteristic, additional product/service characteristics should be defined that strongly affect that customer requirement.
4. If several customer requirements have identical relationships with product/service characteristics, these customer requirements probably need to be broken down to another level of detail for analysis in the product planning matrix.
5. If there are many weak relationships identified between customer requirements and product/service characteristics, these relationships should be examined in more detail.
6. If the relationships identified form a diagonal line through the relationship matrix, customer requirements may contain the language of the product/service characteristics (the voice of the supplier). This is an indication that more emphasis must be placed on the voice of the customer, as opposed to the voice of the supplier, when defining customer requirements.
7. If most of the relationships identified between customer requirements and product/service characteristics form a small distinct block somewhere within the relationship matrix, both customer requirements and product/service characteristics associated with this area of the matrix should be broken down to another level of detail.

8. If a single product/service characteristic has relationships with nearly all of the customer requirements, the product/service characteristic may need to be broken down to another level of detail, or this product/service characteristic should be reviewed to assure that it does not include references to interim product characteristics, process characteristics, process control requirements, or other information that is accounted for in other QFD matrices.
9. If a single customer requirement has relationships with nearly all product/service characteristics, the customer requirement may need to be broken down to another level of detail, or the customer requirement may specify interim product characteristics, process characteristics, process control requirements, or other information that is accounted for in other QFD matrices.
10. If your product or service rates higher than the competition in meeting certain customer requirements, then it should also have better ratings for the associated product/service characteristics, and vice versa.
11. If there is a customer requirement that is very important to the customer, but is not well satisfied by your product/service or by that of your competition, then this is an area in which a major competitive advantage could be obtained if significant improvements were made in your product/service to address this requirement.

Having completed a House of Quality, you should have a very good idea of the relative importance of specific customer requirements and associated product or service characteristics. You should have identified areas in which a competitive advantage might be gained, and in which compromises might have to be made in product development. You should also have developed target values for product/service characteristics, and methods for measuring whether these product/service requirements are being met.

SECTION III: THE VOICE OF THE CUSTOMER

III. THE VOICE OF THE CUSTOMER

Once a customer, a project, and a project time objective have been established, the voice of the customer becomes the foundation for the QFD project. Therefore, it is vitally important to develop as accurate an approximation of the customer's voice as possible.

Types of Product "Quality"

There are three types of "quality" that should be defined through the voice of the customer. These are:

One-dimensional qualities. These are features that customers specifically request. If these features are present, customers are pleased. If these features are absent, customers are not satisfied.

Expected qualities. These are features that are considered essential and, therefore, are often taken for granted and not specifically requested. If these features are present, customers are satisfied. If these features are absent, customers are not satisfied.

Exciting qualities. These are features that customers may not realize are possible. Such features may relate to new technology. Because customers do not realize that these features are possible, they do not specifically request them. If these features are present, customers are surprised and very pleased. If these features are absent, customers are not unsatisfied.

Because customers are likely to specify only one-dimensional qualities, it is important that the QFD project team has the means or knowledge necessary to identify expected and exciting qualities. To help define expected qualities, customers should be asked specifically about those qualities they consider essential. To help define exciting qualities, customers should be asked specifically about features they would like in your product if current technologies and accepted practices were not constraints.

Sources of the Voice of the Customer

There are many potential sources for the voice of the customer. Table 1 can be used to compare these sources from the standpoint of the quality of information they provide, and the resources that are required for their utilization.

Table 1. Voice Of The Customer Sources.

	Information	Complexity	Sample	Bias	Time	Cost
INTERVIEWS						
Face to Face	Direct	Medium	Small	No	High	High
Telephone	Direct	Medium	Small	No	High	High
FOCUS GROUPS	Direct	High	Small	No	High	High
OBSERVATIONS						
Clinics	Direct	High	Small	No	High	High
Displays	Direct	High	Small	No	High	High
FIELD CONTACTS						
Sales Meetings	Direct	Low	Small	Yes	Low	Low
Service Calls	Direct	Low	Small	Yes	Low	Low
Trade Shows	Direct	High	Medium	Yes	High	High
DIRECT VISITS	Direct	High	Medium	Yes	High	Medium
EMPLOYEE FEEDBACK	Direct	High	Medium	Yes	High	Medium
SURVEYS						
Mail	Indirect	Medium	Large	Yes	High	High
Telephone	Direct	Medium	Medium	Yes	High	High
Comment Cards	Indirect	Medium	Large	Yes	High	Low
Point of Purchase	Indirect	Medium	Large	Yes	High	Low
SALES RECORDS						
Monthly Sales	Indirect	Low	Large	Yes	Low	Low
Sales Contacts	Indirect	Low	Large	Yes	Low	Low
Replacement	Indirect	Low	Large	Yes	Low	Low
Part Sales	Indirect	Low	Large	Yes	Low	Low
COMPLAINTS						
Letters	Direct	Low	Large	Yes	Low	Low
Cards	Direct	Low	Large	Yes	Low	Low
WARRANTY DATA						
Service Records	Direct	Low	Large	Yes	Low	Low
Service Workers	Direct	Low	Large	Yes	Low	Low
Return Cards	Direct	Low	Large	Yes	Low	Low
TOLL-FREE HOTLINE	Direct	Low	Large	Yes	High	High
PUBLICATIONS						
Government	Indirect	Low	Large	Yes	Low	Low
Independent	Indirect	Low	Large	Yes	Low	Low
Trade Journals	Indirect	Low	Large	Yes	Low	Low
Consumer	Indirect	Low	Large	Yes	Low	Low

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The Voice of the Customer Table

Once enough information has been collected to adequately approximate the voice of the customer, this information must be organized to facilitate the conversion of the voice of the customer into specific customer requirements for the House Of Quality. A tool that can be used to help define specific customer requirements is the Voice Of The Customer Table (VOCT) shown in Figure 8. Following is a description of each column of the VOCT.

Demographics. This column is for relevant information about each individual providing a voice of the customer statement. This information can be used by the project team to weigh the validity and importance of each particular voice. For example, this column might contain information about a customer's years of experience using your particular product or service, his job responsibilities, etc.

Voice of the Customer. This column is for statements of the customer's wants, needs, desires, or requirements in the exact words of the individuals who have provided the information.

Contextual Information. This column can be used for identifying or clarifying the context of each individual's statement about what they want in the product or service. Based on each individual's statement, this contextual information can include:

- Who uses, or will use it?
- What is it used for, or could it be used for?
- When is it, or will it be used?
- Why is it, or could it be used?
- How is it, or will it be used?

Reworded Statement. This column is used to reword the voice of the customer statements so that the actual customer wants expressed in the statements are made clearer. Project team members can create several paraphrased versions of each voice of the customer statement to help develop these reworded statements.

Customer Requirement. This column is for the identification of specific customer requirements from the reworded statements. Each customer requirement must be a positive statement, must express a single requirement, must be clear to every project team member, must be traceable back to a voice of the customer statement, must be devoid of numbers, and must be devoid of words referring to function, interim product characteristics, process characteristics, and process control characteristics.¹ A single customer statement may include several customer requirements.

¹If a project team decides to use the Matrix of Matrices, then the customer requirements, or "Demanded Quality," developed for the A-1 matrix, must also be devoid of words referring to areas covered by the other 29 matrices such as cost, reliability, etc.

All Other Columns. All other columns are used to identify those elements of customer statements that refer specifically to product/service items that are addressed in matrices other than the product planning matrix. These items might include function, interim product characteristics, and process characteristics.²

Once a VOCT has been completed, the project team should have a list of specific, singular customer requirements that are traceable back to specific voice of the customer statements. All project team members should have a mutual understanding of these customer requirements. These customer requirements can now be used as the basis for an affinity diagram, a tree diagram, and, finally, the customer requirement axis of the product planning matrix. The VOCT might also have captured customer-provided information, such as functional requirements, that can be referenced in creating other QFD matrices.

²Again, if a project team decides to use the Matrix of Matrices, these other columns of the VOCT might include customer information specifically referencing function, cost, reliability, etc.

SECTION IV: OTHER QFD MATRICES

IV. OTHER QFD MATRICES

A QFD project is complete when the project team has met its objectives. Many QFD projects do not go beyond the development of the product planning matrix. Having completed the product planning matrix, the project team will have:

Improved communication. The analysis will have provided opportunities for significant discussions with customers, and between organizations and individuals within the supplier organization.

Gained understanding of customer desires. The analysis will have provided an understanding and appreciation of the customer's wants and needs.

Established product characteristic priorities. The analysis will have resulted in an understanding of the product characteristics that are most important for meeting customer requirements.

Evaluated the competition. The analysis will have provided a better understanding of how well competitors products/services are meeting the needs of the customer.

Determined where high payoff can occur. Areas will have been identified where improvement in product/service characteristics could have a significant effect on customer satisfaction, sales, and competitiveness.

Having completed the product planning matrix, however, the project team may feel that additional detail is required in some areas, or that a detailed implementation plan is required to help translate customer demands into specific supplier organization actions.

At this point, the project team should examine the available tools for continuing the QFD process beyond the product planning matrix. It is possible to use matrices from both the four-matrix approach and the Matrix of Matrices approach, depending on which matrices are considered appropriate by the project team. This manual will continue to focus upon the four-matrix approach to QFD shown in Figure 1.³

³For more detailed instructions on the use of the Matrix of Matrices approach to QFD, refer to, Better Design In Half The Time, Implementing Quality Function Deployment In America, third edition, by Bob King, GOAL/QPC, 1989; and, Quality Function Deployment, Integrating Customer Requirements Into Product Design, by Yoji Akao of Tamagawa University, Productivity Press, Cambridge, Massachusetts, 1990.

The Product Design Matrix

The next step in the QFD process beyond the creation of the product planning matrix is the creation of the product design matrix. The product design matrix is used to translate important product/service characteristics into necessary interim product and part characteristics. An example of the product design matrix is provided in Figure 9. Following are descriptions of each part of the product design matrix.

Important Product/Service Characteristics

The important product/service characteristics are transferred from the top axis of the product planning matrix to the left axis of the product design matrix. The target values and relative weights for each of these product/service characteristics are also transferred to the product design matrix. It may be useful for the project team to develop a Function Analysis Matrix, Figure 10, to assure that all important product/service characteristics have been included. A function analysis matrix has product functions identified along the left axis and the product/service characteristics from the product planning matrix along the top axis, and is completed in the same way as the product planning matrix. The resultant relationship matrix is used to identify those product/service characteristics that are important relative to product functionality. This matrix is often called "the voice of the engineer."

Interim Product/Part Characteristics

A breakdown of the product is defined from primary interim products down to specific pieces. Affinity and tree diagrams are used as necessary to help organize and prioritize these interim products. A meaningful level of interim product/part detail is selected, and the characteristics of these interim products/parts are used along the top axis of the product design matrix.

Relationship Matrix

The relationship matrix is used to identify relationships between the overall product/service characteristics and the interim product/part characteristics. The same symbols and values are used that were used in the product planning matrix.

Absolute Weight, Interim Product/Part Characteristics

Interim product/part characteristic absolute weights are calculated by multiplying scores for each relationship identified for particular interim product/part characteristics by the associated product/service characteristic relative weights, and summing these for each interim product/part characteristic.

Relative Weight, Interim Product/Part Characteristics

Interim product/part characteristic relative weights are calculated by dividing each interim product/part characteristic absolute weight by the total of all interim product/part characteristic absolute weights and multiplying each of these numbers by 100.

Interim Product/ Part Characteristics			Interim Product			Interim Product					
			Interim Product	Interim Product		Interim Product	Interim Product				
Important Product/Service Characteristics	Target Value	Relative Weight	Part Characteristic	Part Characteristic	Interim Product Char.	Part Characteristic	Part Characteristic	Interim Product Char.	Part Characteristic	Part Characteristic	Interim Product Char.
Absolute Weight											
Relative Weight											
Target Value											

● 9, Strong Relationship
 ○ 3, Moderate Relationship
 △ 1, Weak Relationship

Figure 9. The Product Design Matrix.

Interim Product/Part Characteristic Target Values

These interim product/part characteristic target values represent what the project team feels are necessary to provide the important product service characteristics identified in the product planning matrix and, thus, satisfy the most important customer requirements.

Once the product design matrix is complete, the project team should know what interim product/part characteristics are most important to attaining the desired product/service characteristics. The project team should also have developed target values for key interim product/part characteristics to be used as a basis for product design. Now the project team can determine which interim product/part characteristics might present difficulties for the present production processes. This information is used to begin the process planning matrix.

For a product as complex as a complete ship, the identification of important interim product/part characteristics may be difficult using just the product design matrix described above. Alternatively, a matrix identifying system characteristics that address important product characteristics could be created, and then another matrix identifying interim product/part characteristics associated with these system characteristics could be created. This alternative process might allow the project team to more easily generate the information necessary to begin the process planning matrix.

The Process Planning Matrix

The process planning matrix is used to translate important and potentially troublesome interim product/part characteristics into necessary process characteristics. An example of the process planning matrix is provided in Figure 11. Following are descriptions of each part of the process planning matrix.

Important Interim Product/Part Characteristics

The important interim product/part characteristics are transferred from the top axis of the product design matrix to the left axis of the process planning matrix. The target values and relative weights for each of these interim product/part characteristic are also transferred to the process planning matrix.

Process Steps and Characteristics

Process steps are identified for each important interim product/part and then the controllable process characteristics for each step are identified. These controllable process characteristics are essentially equivalent to process parameters or settings. A Failure Mode and Effects Analysis (FMEA), Figure 12, might be useful at this point to assure that all important process steps have been identified. A FMEA simply identifies the potential failure modes of all process steps, and then identifies the potential effects of each failure mode. Those process steps with higher potential for failure, or for which a loss of process control would likely result in unacceptable variance in interim product/part characteristics, should be included in the process planning matrix.

Relationship Matrix

The relationship matrix is used to identify relationships between the interim product/part characteristics and the process characteristics. The same symbols and values are used that were used in the product planning relationship matrix.

Absolute Weight, Process Characteristics

Process characteristic absolute weights are calculated by multiplying scores for each relationship identified for particular process characteristics by the associated interim product/part characteristic relative weights, and summing these for each process characteristic.

Relative Weight, Process Characteristics

Process characteristic relative weights are calculated by dividing each process characteristic absolute weight by the total of all process characteristic absolute weights and multiplying each of these numbers by 100.

Process Characteristic Target Values

These process characteristic target values represent what the project team feels are necessary to provide the important interim product/part characteristics identified in the product design matrix and, thus, satisfy the most important product/service characteristics and customer requirements. These target values can be used to determine whether current production processes have the required capabilities, or whether current processes need to be improved or replaced.

In a shipbuilding environment, the development of process planning matrices could become an overwhelming undertaking because of the huge number of interim products, parts, and process steps associated with a complete ship. If a shipyard has done a good job standardizing and classifying its interim products, it would probably be possible to complete a process planning matrix for each interim product type. Otherwise, the development of these matrices is reasonable

Part/Interim Product ID	
Process Function	
Potential Failure Mode	
Potential Effects	
Potential Causes	
Frequency	
Degree of Influence	
Criticality	
How Detected	
Suggested Countermeasure	
Results	

Figure 12. Failure Mode Effects Analysis.

only if the project team has clearly identified the few specific interim products/parts that are vital, that will probably be difficult to produce, or for which the production process is unproved or not well understood, and those few process steps that would cause critical problems if they were to fail.

The Process Control Planning Matrix

The process control planning matrix is used to determine the degree of control required for each important production process identified in the process planning matrix. The objective of controlling each process is to prevent total process failure and to minimize process variation. Process control planning matrices are more flexible in format than the other matrices. Following is a description of each section of the process control planning matrix shown in Figure 13.

Interim Product/Part Identification

This column is for the important interim products or parts identified from the product design matrix.

Interim Product/Part Characteristic Target Values

These target values are taken directly from the product design matrix for the important interim products and parts identified.

Process Identification

This column is for the important processes identified in the process planning matrix, and associated with the interim product and part characteristic values that have been identified.

Process Characteristic Target Values

These targets are taken directly from the process planning matrix for the important processes that have been identified.

Remaining Columns

Additional columns are used to identify how the particular process characteristic target values will be maintained. Requirements identified might include training, maintenance, statistical process control, inspection, and resources (equipment and personnel).

When the process control planning chart is completed, the project team should have established all the process control procedures necessary to assure that key interim products and parts can be produced with the characteristics that will result in overall product/service characteristics that meet the customer requirements.

SECTION V. QFD CASE STUDIES

V. QFD CASE STUDIES

QFD Prerequisites

Users of QFD must understand that the QFD methodology is built upon a successive approximation of the voice of the customer. The QFD process facilitates the assimilation of this approximate perception of what the customer wants into a plan of action. This means that:

Every contribution is equally valuable and useful. No one person has enough perspective to be absolutely "right" with regard to identifying what the voice of the customer is saying. The objective is to gain as broad and accurate an approximation as possible of the voice of the customer through the open consideration of all available information and through the views of every project team member.

No input is to be criticized. Arguing is not appropriate. Positive discussion and critique of ideas is a necessity.

Diversity in project team membership is important. Membership should represent as many levels of project-related activity as practical (management, staff, engineering, planning, trades, etc.). This will increase the probability of obtaining useful results that can be successfully implemented.

Project team members should have a legitimate interest in the project, should have knowledge useful to the project, and should be knowledgeable of, and committed to, the QFD process.

Formal methods should be established to assure that all project team members have equal opportunity to contribute, i.e. select a leader, raise hands to speak, allow only one participant to speak at a time, self-police against inappropriate criticism.

The QFD methodology must be structured, disciplined, and systematic to assure that all possible representations of the voice of the customer are identified and considered, and also to provide traceability from the action plans derived during the QFD process back to the specific representations of the voice of the customer.

The project team should strive for consensus at each step in the QFD process. It is sometimes easy, during this process, which is by definition a process of successive approximation, to get bogged down in issues and details that have little overall significance. The objective of QFD is to identify and organize the key issues that the voice of the customer has identified, and to develop action plans that address these key issues.

It is not against the rules to go back in the QFD process and change things previously done if additional insight has been acquired by the project team. Just because the project team makes a decision at one point in the process does not mean that the decision has to be final.

Case Study #1: Offshore Supply Boat

Create and analyze a House Of Quality/product planning matrix using the information and customer requirements provided below. Use brainstorming, affinity diagrams, and tree diagrams as necessary to identify and organize product characteristics related to the customer requirements. This case study does not require analysis and structuring of the voice of the customer; the customer requirements given can be assumed to be the result of such an analysis.

The Customer: Owner/operators of offshore supply vessels in the Gulf of Mexico.

Area of Desired Improvement/Breakthrough: These owner/operators want the next generation of offshore supply vessels to be better all-around than the vessels operating today.

Time Constraint: Because of the Persian Gulf war and the associated uncertainty about Middle Eastern oil supplies, oil production and exploration activity in the Gulf of Mexico showed some signs of recovery this past year. A few contracts have already been let for new offshore supply vessels. It is expected that demand for these vessels will increase as the present economic recession ends. A product development time frame of four months, from concept to completion of detailed production plans, is necessary for a builder/supplier to be in a competitive position once demand increases.

The Supplier: You are a small U.S. shipbuilder in the Gulf of Mexico region. You have experience building and repairing tugs, fishing trawlers, offshore supply vessels, dinner/excursion vessels, patrol craft, and other similar vessels in steel and aluminum up to 200 ft. in length. You have in-house design capability. Your total number of personnel has ranged from 10 to 175; current number of personnel is 87.

<u>Customer Requirements:</u>	<u>Customer Weight</u>	<u>Your Current Rating</u>	<u>Competitor Option "A"</u>	<u>Competitor Option "B"</u>
• Long range	4	3	4	3
• Can operate in bad weather	2	4	3	3
• Safe for the crew	5	4	3	4
• Easily maintained	4	3	2	5
• Versatile in cargo types/combinations	4	4	3	3
• Durable; will last long	3	3	3	4
• Economical to operate	5	3	2	4
• Comfortable for crew	2	3	4	2
• Fast	5	3	5	2
• Easy to operate	3	3	4	3
• Well built	4	3	3	4

Customer Weight: 1-not very important to the customer.
5-extremely important to the customer.

Current/Option Ratings: 1-not meeting customer requirement well.
5-meeting customer requirement extremely well.

Case Study #2: Submarine "Ocean Dog"

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Navy personnel who have an interest in the next generation of attack submarine.

Area of Desired Improvement/Breakthrough: These Navy personnel want the next class of attack submarines, the "Ocean Dog," to be state-of-the-art with respect to the mission requirements of an attack sub.

Time Constraint: The Navy is expecting a contract design, preliminary production engineering, and a cost proposal for construction of the first ship of the class to be completed by both your shipyard and your competitor in three years.

The Supplier: You are the operations managers of a major U.S. shipbuilder with nuclear submarine design and construction experience.

Background: Your shipyard and another major shipyard with similar experience have each been awarded a contract for contract design and initial production engineering for the new class of attack submarine, and for a cost proposal for the construction of the first ship of the new class. At the end of this three-year contract, the Navy will choose one of the two shipyards to continue with detailed design, detailed production engineering, and construction of the first ship of the class.

Customer Statements:

- 1) Rear Admiral, "Ocean Dog" program head: "The 'Ocean Dog' must have the best integrated sonar and weapons-control systems that will be available when the ship is constructed. And the ship must be producible."
- 2) Rear Admiral, Chief Engineer of the Navy: "The 'Ocean Dog' must be able to go deeper than present attack subs, must be as quiet at flank speed as present subs are at low speed, and must be safe for the crew."
- 3) Captain, most experience active attack sub skipper in the Navy: "The next attack sub must be faster, more maneuverable, deeper diving, much quieter, easier to operate in all scenarios, and must be able to detect other vessels more effectively."
- 4) Captain, recently promoted to skipper of an attack sub, formerly a chief weapons officer: "The weapons system on the new sub must be more versatile, that is, capable of launching different types of weapons, and it must be reusable/loadable during a mission. Present vertical launch systems can launch only cruise missiles, and can be loaded only from external sources while on the surface using an independent crane. Present torpedo tubes can launch only torpedoes."
- 5) Lieutenant, engine room officer of an attack sub: "I hope the next generation of subs is more comfortable for the crew, and easier to maintain."
- 6) Master Chief, submarine reactor control electronics expert: "I wish the technical manuals were easier to use and understand."
- 7) Secretary of Defense: "The next generation of attack submarine, the 'Ocean Dog,' will be the most powerful weapon system of its kind in the world. It will be capable of seeking out and destroying enemy submarines and surface ships, and launching strikes against land-based targets without being detected. The 'Ocean Dog' will also be a good value for the taxpayer."

Case Study #3: Submarine Structural Interim Product

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Shipyard personnel who work in the structural assembly trades and who will build the next generation of attack submarine.

Area of Desired Improvement/Breakthrough: These shipyard personnel want the next class of attack submarines, the "Ocean Dog," to be easier to build than present subs.

Time Constraint: The shipyard is expecting its contract design, preliminary production engineering, and cost proposal for construction of the first ship of the class to be complete in three years. The detail design and lead ship construction contract is expected shortly thereafter with fabrication for the lead ship starting within four years.

The Supplier: You are the operations managers of a major U.S. shipbuilder with nuclear submarine design and construction experience.

Background: Your shipyard and another major shipyard with similar experience have each been awarded a contract for contract design and initial production engineering for the new class of attack submarine, and for a cost proposal for the construction of the first ship of the new class. At the end of this three-year contract, the Navy will choose one of the two shipyards to continue with detailed design, detailed production engineering, and construction of the first ship of the class.

Your structural fitting and welding trades are responsible only for assembly work, and are not responsible for the fabrication of structural piece-parts, which might include initial blasting and coating of raw material, initial layoff, burning, shaping, edge prep, and affixing piece-part identifications.

Customer Statements:

- 1) Superintendent of structural fitters: "It would be nice if the fabrication trade could cut, roll, and edge prep shell plates and frames accurately enough so that we would not require excess material for fit-up. Can the designers help this situation for the next type of sub?"
- 2) Structural fitter foreman: "My job would be much easier if there were some uniformity to the structure of the hull sections in the parallel mid-body of the ship. Frame spacing, frame sizes, shell thickness, and circumferential shell seam spacing are not consistent in the present boats."
- 3) First class structural fitter: "I want the drawings, work instructions, and reference lines to be right."
- 4) Superintendent of structural welders: "Controlling weld distortion is our biggest problem on the present subs. Whatever design could do to help solve that problem would be great."
- 5) Structural welding engineer: "Simplifying the structural design would be a tremendous help from the standpoint of minimizing distortion and improving welder access and work position. We should also try to design for maximum use of automatic and semiautomatic welding processes."
- 6) Structural welding foreman: "Any pieces that have been fabricated incorrectly or poorly trimmed by the fitters will require weld build-up, increasing the chances for distortion, cracking, NDT failure, and rework. This can be a huge problem with major joints, such as when joining hull sections or installing a hard tank that must withstand depth pressure."
- 7) Structural welder: "Welding inside all of these tanks that are integral to the hull structure is very slow and tedious work, and is sometimes dangerous because of the cramped conditions and the preheat. Carbon arcing to repair cracks inside one of these tanks is just plain scary. It would be nice to have more room in these tanks to work, or to not have to go in the tanks to weld at all."

Case Study #4: Commercial Ship Design For Maintainability

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Owner/operator of a fleet of merchant ships of various types.

Area of Desired Improvement/Breakthrough: This owner/operator wants the new ships that he purchases to be designed to facilitate easier, faster, and less expensive maintenance, repair, and overhaul.

Time Constraint: This owner/operator will contract for the replacement for the oldest ship in his fleet, a bulk cargo ship, in six months. Your proposal is due to him in three months.

The Supplier: You are the operations managers of a major U.S. shipbuilder with past merchant ship new construction, repair, and overhaul experience. You would like to again build merchant ships. You have in-house design capability.

Background: An owner/operator of fifteen merchant ships has given you an RFP to bid on a replacement for his oldest ship. This owner/operator's fleet averages approximately seventeen years of age. He will be contracting for gradual replacement of the eleven oldest of his fifteen ships over the next eight years, starting in six months. You will, of course, be attempting to compete in the global shipbuilding market as you pursue this owner's business. Obviously, if you were to obtain his first contract, success on this ship would be very important to maintaining a relationship with this owner for future contracts, and for establishing your reputation as a competitive merchant shipbuilder. The owner/operator expects significant improvements or breakthroughs in a number of areas of design for his new ship, including maintenance and overhaul improvement.

Customer Statements:

- 1) "I want to minimize my operating expenses in the future partially by reducing the number of major overhauls required during the life of my ships and by minimizing the cost and duration of maintenance and overhaul work."
- 2) "The ship's crew must have very good access to all critical distributive systems and components while underway."
- 3) "Shipyard personnel must have good access to all distributive systems and components during overhaul and repair."
- 4) "The design must facilitate complete overhaul of all major components."
- 5) "Tank interiors, sea water systems, other systems carrying corrosive media, shafts, bilges, and hull exterior should have a minimum of corrosion at overhauls."
- 6) "All components chosen should have a documented high degree of reliability and should be widely available."
- 7) "The crew must be able to monitor and diagnose the condition of all major components on a real-time basis while underway."
- 8) "Required preventative maintenance should be minimized."

Case Study #5: Pipe Spools/Details

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Your shipyard personnel who work in the pipe fitting trades and who have experience building, repairing, and overhauling merchant ships.

Area of Desired Improvement/Breakthrough: These shipyard personnel want all pipe spools to fit properly during the outfit assembly processes.

Time Constraint: Your shipyard is pursuing a merchant ship contract. Executive management wants a recently identified, yet apparently chronic, pipe-fitting problem resolved quickly to justify the cost estimates that are being submitted as part of the proposal for merchant ship work. Executive management has given your project team two months to develop and implement an action plan. The shipyard's proposal for construction of the merchant ship is due in three months.

The Supplier: You are the operations managers of a major U.S. shipbuilder with past merchant ship new construction, repair, and overhaul experience. You would like to again build merchant ships. You have in-house design capability.

Background: An owner/operator of fifteen merchant ships has given your shipyard an RFP to bid on a replacement for his oldest ship. This owner/operator will be contracting for gradual replacement of the eleven oldest of his fifteen ships over the next eight years, starting in six months.

Although you would like to build merchant ships again, some of your current work practices, which have until now been considered "normal shipbuilding practice" (such as reworking pipe spools during assembly processes), are now considered unacceptable if you are to be competitive.

Customer Statements:

- 1) Pipefitter foreman: "Its fairly normal practice to work smaller diameter pipe spools around a bit on board to avoid interferences. The larger diameter spools that have interference problems get sent back to the fab shop for rework. Sometimes the fab shop sends them right back saying that they were fabricated to the correct dimensions. The spool might match the fab sketch but will not fit on the ship."
- 2) Pipefitter foreman: "There are periods of time when a good percentage of the pipe spools will come to a hull block or to the ship with flange rotations that either do not match the installation drawing or do not match the spools or components that they are supposed to fit."
- 3) First class pipefitter: "Half of the time the lines people have either put so many lines in a space that you don't know which ones to use, or they haven't put any lines in the space at all and we have to measure as best we can off of frames, bulkheads, and decks."
- 4) First year pipefitter apprentice: "Why are the installation drawings wrong all of the time?"
- 5) Master pipefitter: "We get some spools that have been dinged up or bent, and occasionally we get a spool that has the wrong ID number or that has been cut short. But there are enough of us down here who know enough to usually catch these mistakes. If the mistakes are minor we just fix them ourselves rather than hassle with sending them back to the fab shop."

Case Study #6: Water Tight Doors

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: The customers are the fleet sailors represented by the NAVSEA Platform Directorate SEA 91.

Area of Desired Improvement/Breakthrough: A water-tight door that is easy to maintain and operate, and not too expensive to build.

Time Constraint: The Admiral in the SEA 91 position expects to leave his position within the next year and would like to have the new door designed and a prototype built before he leaves.

The Supplier: You are the team leader in the NAVSEA design code SEA 05xx responsible for water-tight doors.

Background: Present water-tight doors are of a design that existed before World War II. They are a proven door from the standpoint of damage control. However, they are heavy and must be dogged in several areas when secured. It takes a long time to dog a door, and frequently it is difficult to undog. There is a maintenance requirement to chalk test the door every 6 months to assure that the door is water tight. Frequently the doors fail the test and must be adjusted or the gasket must be replaced. On the other hand, NAVSEA has not heard a lot of complaints about the doors and SEA 91's complaint is one of many problems that face SEA 05.

Customer Statements:

- 1) SEA 91 to SEA 05: "When I was out at the Arizona Memorial it came to me that the ____ doors we use now are the same as we used then. They are no ____ good! When are we going to get a satisfactory door? My washing machine door isn't hard to operate and it doesn't leak, why don't we design a door like that?"
- 2) SEA 05 to SEA 91: "Doors haven't been high on our priority list, but we'll take a look at them and see what we can do."
- 3) SEA 05 to Design Leader: "SEA 91 says our doors are no ____ good. Frankly, I think he is right. My experience with them hasn't been good either but they are proven and we must not sacrifice the doors' effectiveness to satisfy other concerns. Go take a look at it, see what the complaints are, and what you can come up with."
- 4) Aircraft Carrier Master Chief: "The doors take an extensive amount of time to maintain. If I did what I'm required to do I'd have a team of people doing nothing but water-tight doors. I can't afford that."
- 5) D.C. First Class: "The chalk test requirement is not compatible with the door design. They hardly ever pass. We can't keep up with the requirement so we just groom the doors before our major inspections."
- 6) Ship's Captain: "The other day I couldn't get out of a compartment. Some strong-armed sailor dogged the door so tight I couldn't get it undogged."
- 7) Fleet Maintenance Officer: "Yeah, doors are one of our consistent maintenance items when we go alongside tenders."
- 8) Supply Officer: "I have a hard time keeping gasket material in stock. I'm not sure why we seem to use so much. I have heard complaints that it doesn't stand up to the service very well."
- 9) Shipyard Shipfitter Foreman: "We have to take the doors off in overhauls and frequently cut out the framing in order to widen the passage to get equipment out. The doors usually get straightened as part of the overhaul routine. However, when we weld the bulkhead back with the framing it's hard to hold the alignment so that the door will shut tightly. Consequently we have a lot of trouble with the compartment air tests. We have to adjust the hinges to get everything right."

Appendix "A"

References and Resources

- Prof. Yoji Akao, Tamagawa University, Quality Function Deployment, Integrating Customer Requirements Into Product Design, 1990, Productivity Press.
- Technicomp, Inc., 1111 Chestnut Avenue, 300 Park Plaza, Cleveland, Ohio 44114, 1-800-255-4440.
- GOAL/QPC and Bob King, 13 Branch Street, Methuen, MA 01844, 508-685-3900, Better Design In Half The Time, Implementing Quality Function Deployment In America, third edition, 1989, GOAL/QPC Press.
- American Supplier Institute, Inc., Six Parklane Blvd., Suite 411, Dearborn, MI 48126, 313-336-8877.
- Florida Power and Light-Quality Improvement Department, P.O. Box 14000, Juno Beach, FL 33408-0420, 305-552-4421.

Appendix "B"

Additional Notes On Using Quality Function Deployment

This section is a modified section of the book, Better Designs in Half the Time, by GOAL/QPC.

1.0 Using Quality Function Deployment

1.1 Introduction

Quality Function Deployment (QFD) is a multifunctional planning tool used by management to prioritize customer's demands and to develop reliable and cost effective responses.

QFD is a part of Total Quality Management (TQM). Total Quality Management is a way of doing business with a focus on customer satisfaction. An organization utilizing TQM is usually characterized by an environment of standardization, continuous improvement, and innovation as shown in Figure B-1. The TQM environment is summarized below in Table B-1.

**Table B-1
Customer Driven Master Plan**

Daily Control	Hoshin Planning	Cross Functional Management
<ul style="list-style-type: none"> • Statistical Methods • Work Groups • Standardization 	<ul style="list-style-type: none"> • Continuous Improvement • Vertical Teams • 7 "M" Tools 	<ul style="list-style-type: none"> • Information Systems Audit Tools • Customer/Supplier • Q.A./Q.F.D.

The purpose of this appendix is to focus on QFD. Quality Function Deployment is a key component of cross-functional management, and is used for innovation.

1.2 QFD Options and QFD Strength & Weaknesses

There are two different approaches to QFD: a focused one credited to Don Clausing of Massachusetts Institute of Technology, and a generic one developed by Yoji Akao of Tamagawa Universtiy.

1.2.1 Focused Approach: Clausing

This approach is a modification of the QFD method used to assist in reliability engineering. Its value is its traceability from customer to manufacturing (see Figure B-2). It is very good for developing and improving parts and components, but is awkward for more complex products such as computers, automobiles, and ships. It is good for minor improvements in existing technology, but is not well suited for cost effective innovation. Clausing taught this approach to the American Supplier Institute.

The Total Quality Management/Control Environment

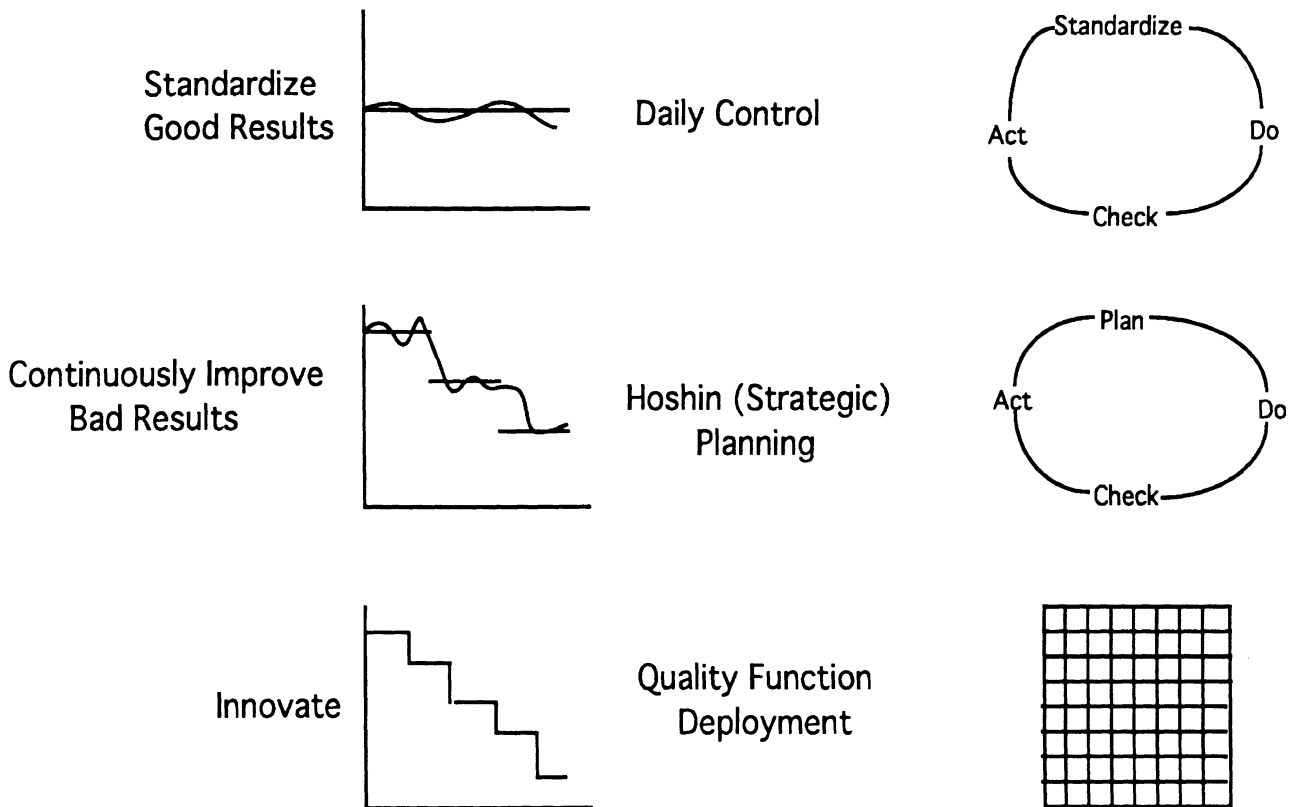


Figure B-1. Functions In A TQM Environment.

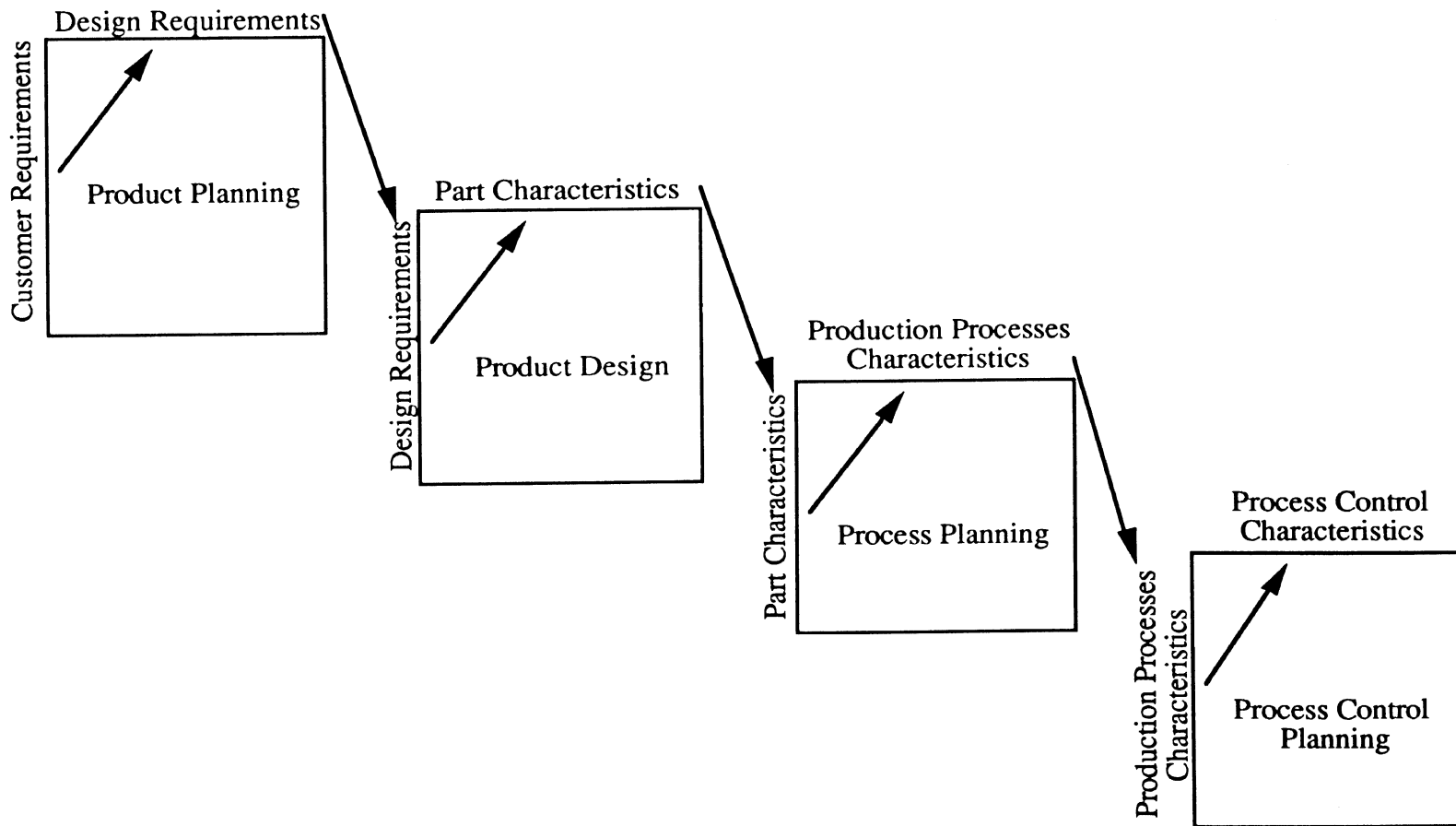


Figure B-2. Focused Approach.

1.2.2 Generic Approach: Akao

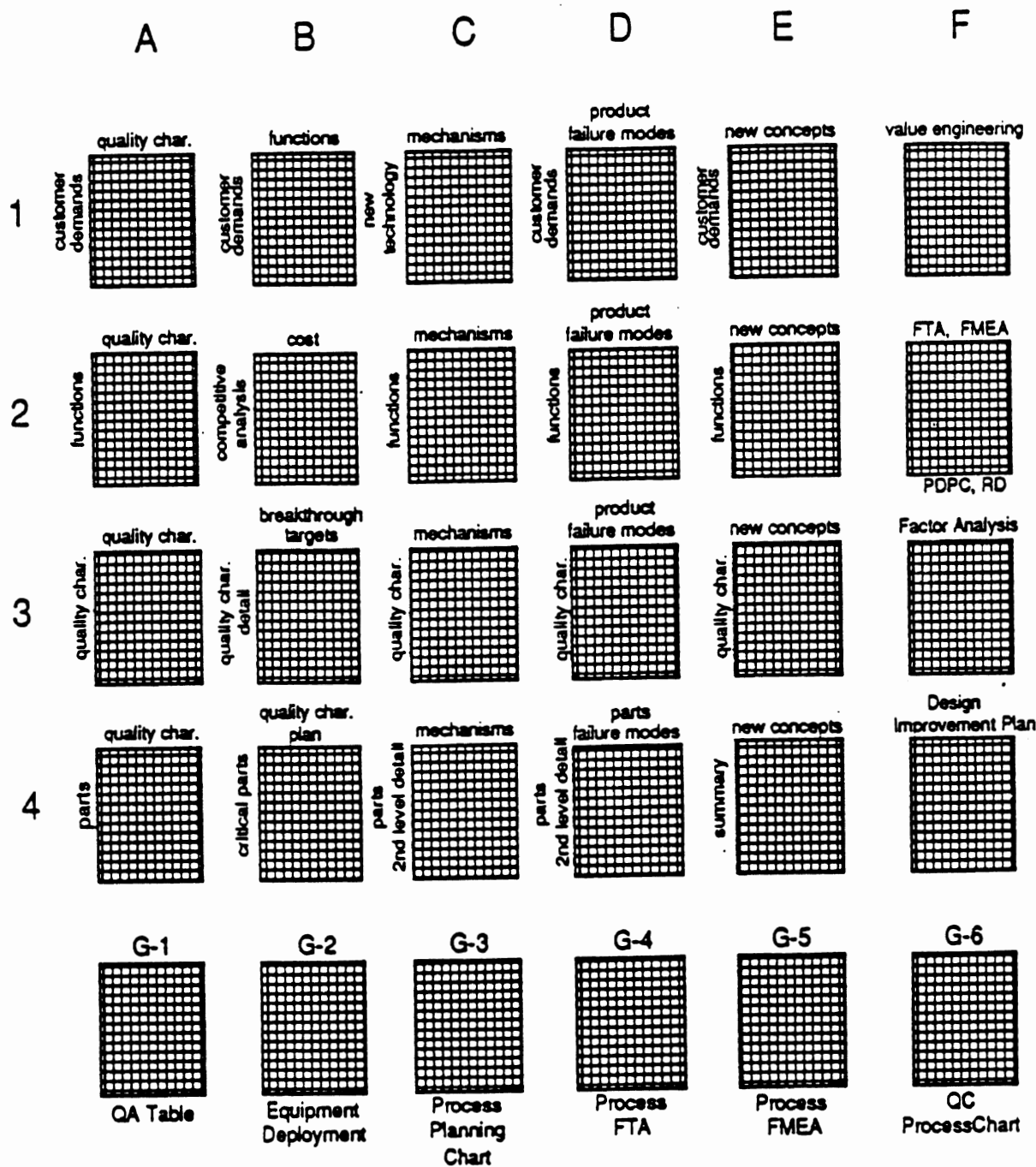
A more generic approach was developed by Yoji Akao in the mid-1980s. Its value was that it included linkages with value engineering and reliability charts such as Failure Mode & Effective Analyses (FMEA) and Fault Tree Analyses (FTA). An adaptation of his charts is presented in Figure B-3 as the "Matrix of Matrices." This adaptation has the benefit of providing a number of different formats for QFD matrices. Its major weakness, apart from its apparent complexity, is its lack of clear implementation steps. An effort has been made to solve this problem by setting up sequence steps for the matrices. Possible sequence steps are shown in Figure B-3.

Legend For Use With Figure B-3.

<u>Purpose to be Achieved</u>	<u>Charts to Use</u>
Analyze customer demands	A1, B1, D1, E1
Critique functions	A2, C2, D2, E2
Set quality characteristics	A1, A2, A3, A4, B3, B4, C3, D3, E3
Identify critical parts	A4, B4, C4, E4
Set breakthrough targets	B2, B3, B4, C1
Set cost targets	B1, C2, C3, C4
Set reliability targets	D1, D2, D3, D4
Select new concepts	E1, E2, E3, E4
Identify breakthrough methods	D4, F1, F2, F3
Identify manufacturing methods	G1, G2, G3, G4, G5, G6

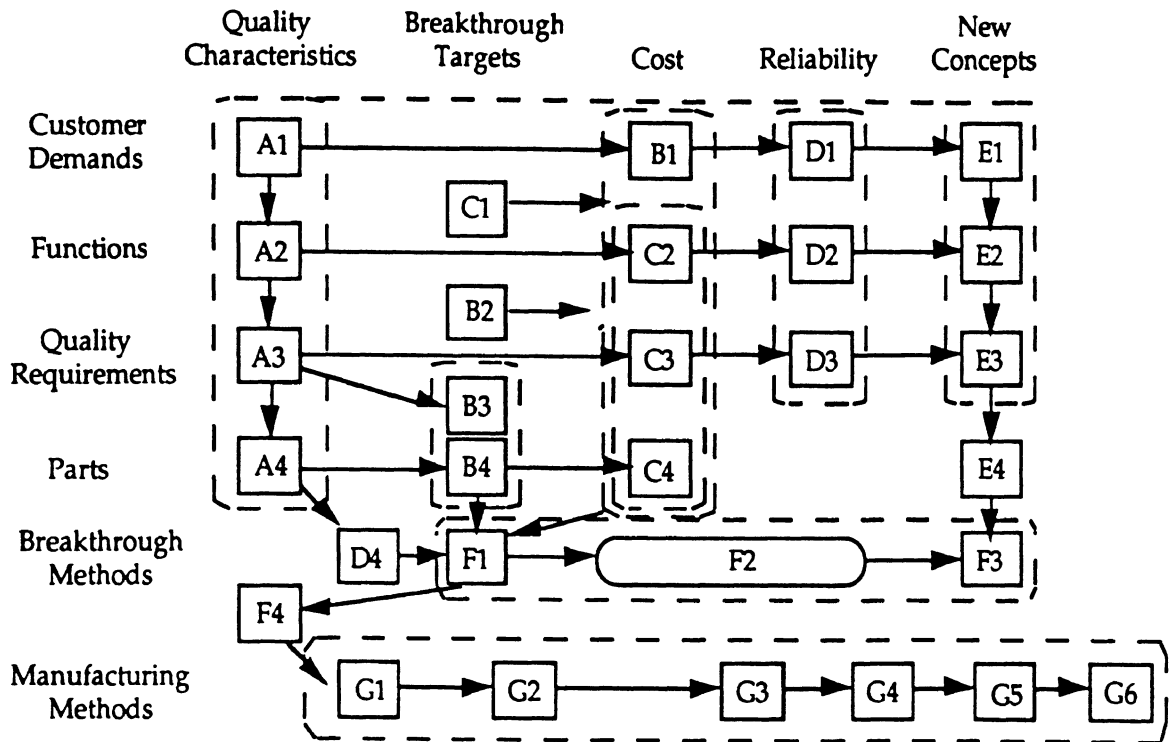
Figure B-4, along with the above legend, shows not only which charts should be completed first, but also identifies the general purpose of each chart. The disadvantage of this figure is that it suggests that the charts are static when, in fact, they are iterative.

Another way to sequence the chart is represented in Figure B-5. This chart has been well received in QFD classes.



Source: GOAL/QPC

Figure B-3. The Matrix of Matrices.



Purpose to be achieved

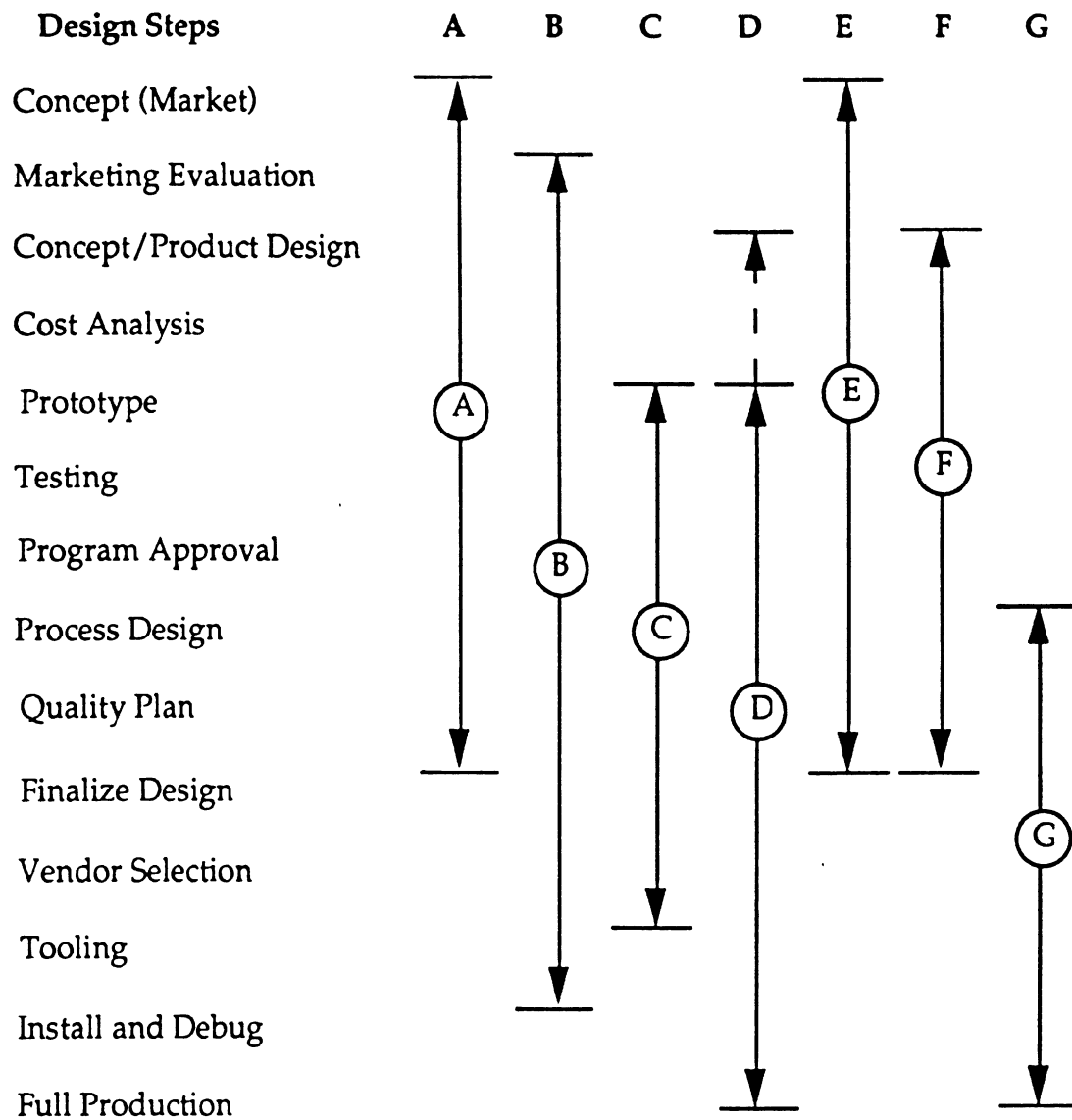
Charts to Use

- Analyze customer demands
- Critique functions
- Set quality characteristics
- Identify critical parts
- Set breakthrough targets
- Set cost targets
- Set reliability targets
- Select new concepts
- Identify breakthrough methods
- Identify manufacturing methods

- A1, B1, D1, E1
- A2, C2, D2, E2
- A1, A2, A3, A4, B3, B4, C3, D3, E3
- A4, B4, C4, E4
- C1, B2, B3, B4
- B1, C2, C3, C4
- D1, D2, D3, D4
- E1, E2, E3, E4
- D4, F1, F2, F3
- G1, G2, G3, G4, G5, G6

Source: GOAL/QPC

Figure B-4. Approaches To The Matrix of Matrices.



Source: GOAL/QPC

Figure B-5. Other Approaches to the Matrix of Matrices.

Appendix "C"

The Seven Management Tools

This section is a modified section of the book, Better Designs in Half the Time, by GOAL/QPC.

1.0 The Seven Management Tools

1.1 Introduction

There are seven management tools that can be used to facilitate project planning and decision making processes. Following are brief descriptions of each of these management tools.

For General Planning

- The Affinity Diagram: used to organize large amounts of data into groupings based on the natural relationship between data elements.
- The Interrelationship Diagram: used to identify and displays interrelated factors involved in complex problems. It also shows the relationships among factors.

For Intermediate Planning

- The Tree Diagram: used to systematically map out hierarchical relationships among data elements or groups of data elements, or to identify the full range of paths and tasks that need to be accomplished in order to achieve a primary goal.
- The Matrix Diagram: used to organize related groups of data such that the relationships, and the importance of the relationships, between individual data elements in each group are apparent.
- Matrix Data Analysis: used to arrange data shown in a Matrix Diagram, such that the relationships identified in the Matrix Diagram can be analyzed in more detail.

- The Process Decision Program Chart (PDPC): used to map out every conceivable event that may occur when moving from a problem statement to possible solutions.
- The Arrow Diagram: used to plan the most appropriate schedule for any task and to control it effectively as it progresses.

2.0 The Affinity/KJ Diagram

The affinity diagram gathers large amounts of data, such as ideas, opinions, and issues, and organizes them into groupings based on the natural relationship between each item. It is largely a creative, rather than a logical, process that occurs during discussion of a project.

The biggest obstacle to planning for improvement is past success or failure. It is assumed that what worked or failed in the past will continue to do so in the future. We therefore perpetuate patterns of thinking that may or may not be appropriate. Continuous improvement requires that new logical patterns be explored at all times.

The KJ Method is an excellent way to get a group of people to react from the creative gut level, rather than from the intellectual, logical level. It also efficiently organizes these creative, new thought patterns for further elaboration. Teams may produce and organize more than 100 ideas or issues in less than an hour. Think of how long that task would take using a traditional discussion process. It is not only efficient, it also encourages true participation because every person's ideas find their way into the process. This differs from discussions in which ideas are lost in the shuffle and are therefore never considered.

2.1 When to Use the Affinity Diagram

The affinity diagram is useful for organizing ideas around nearly any issue. However, there are applications that are more natural than others. The cleanest use of the diagram is in situations in which:

- facts or thoughts are in chaos. When issues seem too large or complex to grasp, use the diagram to map out the issue.
- breakthrough in traditional concepts is needed. When the only solutions are old solutions, use the diagram to expand the team's thinking.

- support for a solution is essential for successful implementation.

The affinity diagram is not suggested for use when the problem is simple, or requires a very quick solution.

2.2 Construction of the Affinity Diagram

The most effective group to assemble an affinity diagram is one that has the knowledge needed to uncover the various dimensions of the issue. The affinity process also seems to work most smoothly when the team is accustomed to working together. This enables team members to speak in a type of shorthand they know from their common experience. There should be a maximum of six to eight members on the team.

The following are the most commonly used construction steps.

1. Phrase the issue to be considered. It works best when it is stated vaguely. An example would be, "What are the issues surrounding Platen 5's support for the new welding process?" There should be no more explanation than that since more details may prejudice the responses toward the "old process."
2. The responses can be recorded in two different ways-
 - a. Record individual ideas on a flip chart pad and then transcribe them onto small cards, one idea per card.
 - b. Record individual ideas directly onto individual cards by a recorder or by the contributor themselves. It must be stressed that ideas should be concise and recorded exactly as stated. The aim should be to capture the essence of the thought.
3. The team should take the cards, mix them together, and spread them out randomly on a large table.
4. The cards can be grouped by the team or assigned to an individual in one of the following ways.

a. Look for two cards that seem to be related in some way. Place those to one side. Now look for other cards that can be related to the first two.

b. Repeat this process until you have all possible cards placed in no more than ten groupings. It may be necessary to duplicate specific ideas that seem to belong in more than one group. Do not force-fit single cards into groupings in which they don't belong. These single cards may form their own grouping or may never find another group.

Note: These are simply groups of ideas that hang together. They are not necessarily categories. It seems to be most effective to have everyone move the cards at will without talking. This prevents team members from getting trapped in semantic battles.

5. Transfer the information from cards onto paper with lines around each grouping. Related clusters should be placed near each other with connecting lines. From this the group can examine the data and make additions, deletions, and modifications.

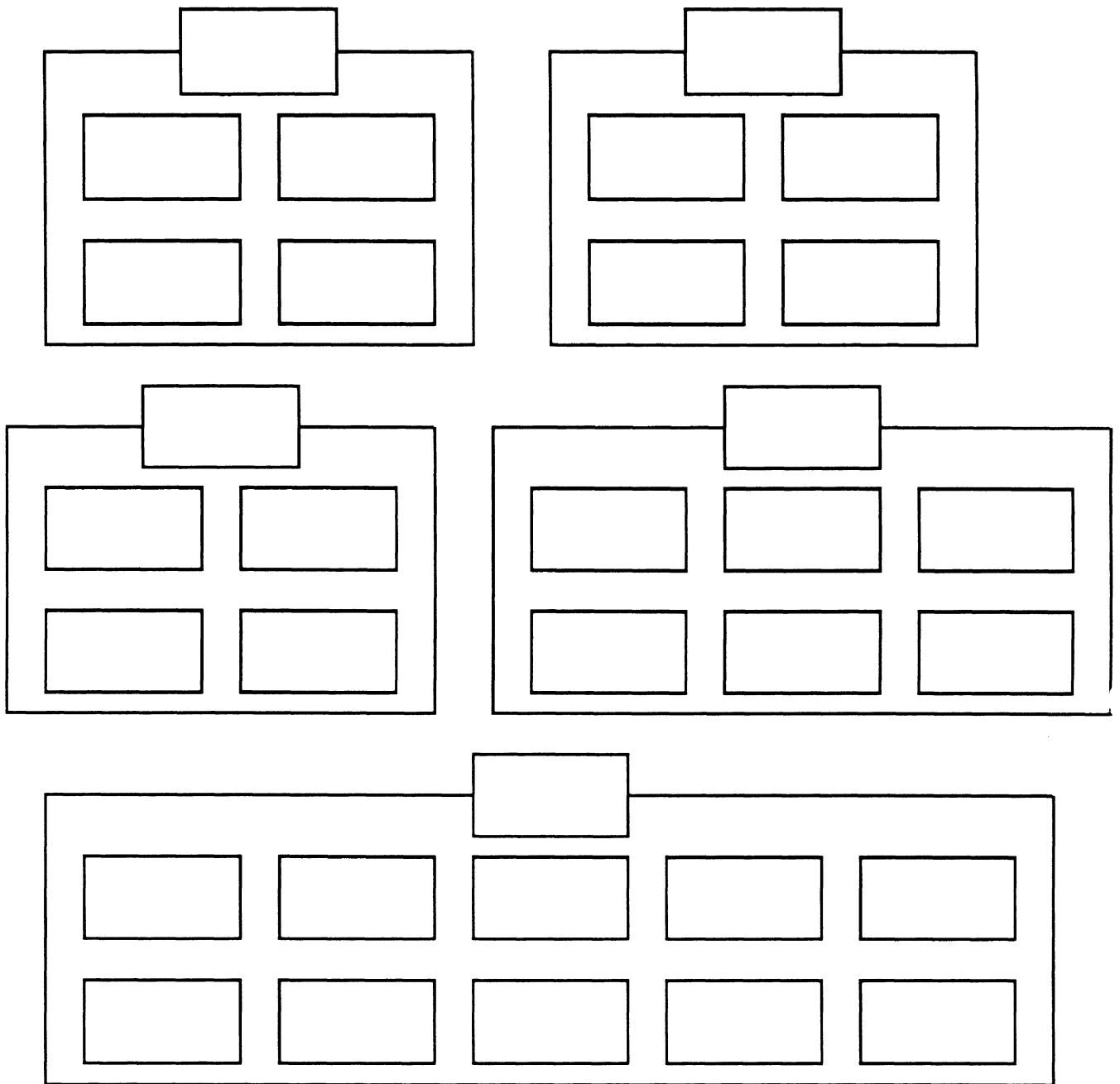


Figure C-1. Affinity Diagram.

3.0 Interrelationship Digraph

3.1 Definition

This tool takes a central idea, issue, or problem and maps out the logical or sequential links among related items. While still a very creative process, the Interrelationship Digraph begins to draw the logical connections that surface in the KJ Method.

In planning and problem solving, it is obviously not enough to just create an explosion of ideas. The KJ Method allows some initial organized creative patterns to emerge, but the Interrelationship Digraph (ID) lets logical patterns become apparent. This is based on the same principle that the Japanese frequently apply regarding the natural emergence of ideas. Therefore, an ID starts from a central concept, leads to the generation of large quantities of ideas, and finally to the delineation of observed patterns. To some this may appear to be like reading tea leaves, but it works incredibly well. Like the KJ, the ID allows those unanticipated ideas and connections to rise to the surface.

3.2 When to Use the Interrelationship Digraph

The ID is exceptionally adaptable to both specific operational issues and general organizational questions. For example, a classic use of the ID at Toyota focused on all of the factors involved in the establishment of a “billboard system” as part of the JIT program. On the other hand, it has also been used to deal with issues underlying the problem of getting top management support for TQC.

In summary, the ID should be used when:

- (a) an issue is sufficiently complex that the interrelationships among ideas are difficult to determine;
- (b) the correct sequencing of management actions is critical;
- (c) there is a feeling that the problem under discussion is only a symptom; and
- (d) there is ample time to complete the required reiterative process.

3.3 Construction of an Interrelationship Digraph

As in the KJ diagram and the remainder of the tools, the aim is to have the right people with the right tools working on the right problems. This means that the first step is to define the necessary blend of people for a group of six to eight individuals.

The construction steps are as follows:

1. Make one clear statement of the key issue under discussion.

Note: The source of this issue can vary. It may come from a problem that presents itself clearly. In this case, the ID would be the first step in the cycle rather than the KJ. The KJ is frequently used to generate the key issues to be explored in the ID.

2. Record the issue/problem statement. It can be recorded by
 - a. placing it on the same type of card as is used in the KJ, or
 - b. writing it on a flip chart.
3. To start the process, place the statement in one of two patterns.
 - a. a centralized pattern in which the statement is placed in the middle of the table or flip chart paper with related ideas clustered around it, or
 - b. a unidirectional pattern in which the statement is placed to the extreme right or left of the table or flip chart paper with related ideas posted on one side of it.
4. Generate the related issues/problems in one of the follow ways.
 - a. Take the cards from a grouping under KJ and lay them out with the one that is most closely related to the problem statement placed next to it. Then lay out the rest of the cards in sequential or causal order.

- b. Do wide-open brainstorming, place the ideas on cards and cluster them around the Central Statement, as in "a" above.
- c. Do wide-open brainstorming but directly onto the flip chart instead of cards. Proceed as in "a" and "b" above.

Note: The advantage of using cards is that they can be moved as the discussion progresses. The flip chart method is quicker, but can become very messy if changes occur.

Note: When using the flip chart method, designate all the related ideas by placing them in a single lined box.

5. Once all the related idea statements are placed relative to the central problem statement, fill in the causal arrows that indicate what leads to what. Look for possible relationships between each pair of ideas identified.

Note: At this step, you would look for patterns of arrows to determine what the key factors/causes are. For example, if one factor has seven arrows coming from it to other issues, while all others had three or fewer, then that would be a key factor. It would be designated by a double-hatched box.

6. Copy the ID legibly and circulate identified key factors to group members.
7. As in the KJ, you may draw lines around groupings of related issues.
8. Prepare to use the identified key factors as the basis for the next tool, the Tree Diagram.

4.0 SYSTEM FLOW/TREE DIAGRAM

4.1 Definition

This tool systematically maps out the full range of paths and tasks that needs to be accomplished in order to achieve a primary goal and every related subgoal. In the original Japanese context, it describes the “methods” by which every “purpose” is to be achieved.

In many ways, the KJ Method and Interrelationship Digraph force the key issues to the surface. The questions then become, “What is the sequence of tasks that need to be completed in order to best address that issue?” or “What are all of the factors that contribute to the existence of the key problem?” The Tree Diagram is appropriate for either question. Therefore, it can be used either as a cause-finding problem solver or as a task-generating planning tool. In either use, it brings the process from a broad level of concern to the lowest practical level of detail.

Another strong point is that it forces the user to examine the logical link between all of the interim tasks. This addresses the tendency of many managers to jump from the broad goal to details without examining what needs to happen in order for successful implementation to occur. It also rapidly uncovers gaps in logic or planning.

4.2 When to Use the Tree Diagram

The Tree Diagram is indispensable when you require a thorough understanding of what needs to be accomplished, how it is to be achieved, and the relationships between these goals and methodologies.

It has been found to be most helpful in situations such as the following:

- When you need to translate ill-defined needs into operational characteristics. For example, a Tree Diagram would be helpful in converting a desire to have an “easy to use VCR” into every product characteristic that would contribute to this goal. It would also identify the characteristics that can presently be controlled.
- When you need to explore all the possible causes of a problem. In this application the Tree Diagram is called a Cause & Effect Diagram or Fishbone Chart. Such a chart could be used to uncover all of the reasons why top management may not support a continuous improvement effort.

- When you need to identify the first task that must be accomplished in reaching a broad, organizational goal. For example, the Tree Diagram could be very helpful in the coordination of Quality Improvement Programs by identifying what is already being accomplished and where the key gaps exist.
- When the issue under question has sufficient complexity and time available for solution. For example, a Tree Diagram would not be particularly helpful for deciding how to deal with a product contamination problem that is shutting down you production line. It could be used to prevent it from reoccurring, but not in deciding on the stop-gap measures to be taken.

Note: In its most common usage the Tree Diagram conceptually resembles the Cause & Effect Diagrams. It is easier to interpret because of its clear, linear layout, and it also seems to create fewer loose ends than the C&E.

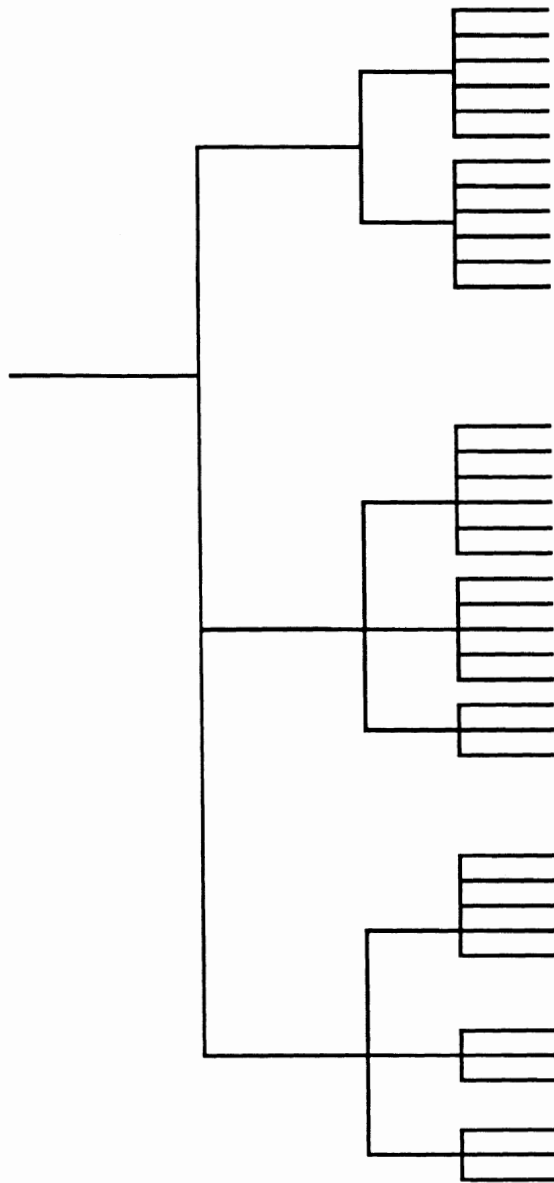


Figure C-3. Tree Diagram.

4.3 Construction of a System Flow/Tree Diagram

It has been shown that these tools are most powerful when used in combination, but they are also very effective when applied singly. With this in mind, the following are the most widely used steps:

1. Agree upon one statement that clearly and simply states the core issue, problem, or goal. This statement may or may not come from a KJ Chart or Interrelationship Diagram.

Note: Unlike the KJ Method, the Tree Diagram becomes more effective as the issue is more clearly specified. This is important since the emphasis is on finding the logical and sequential links between ideas/tasks and not on pure creativity.

2. Once the statement is agreed upon, the team must generate all of the possible tasks, methods, or causes related to that statement. These could follow three different formats.
 - a. Use the cards from the KJ Chart as a foundation. For example, you might take the 10-20 cards that fall under one broad heading as a starting point.
 - b. Brainstorm all of the possible related tasks/methods/causes and record them on a flip chart. These ideas could then be placed on individual cards or rearranged on the flip chart.
 - c. Brainstorm and record directly onto cards for continued use.

Note: When brainstorming, continue to apply to each idea the question "In order to achieve X, what must happen or exist?" Or "What has happened or what exists that causes X?"

3. Evaluate and code all of the ideas with the following:
 - O Possible to carry out
 - L Need more information to see if possible
 - X Impossible to carry out

Note: Code an idea to be impossible only after very careful consideration. "Impossible" must not be equated with "we've never done it before."

4. Construct the Actual Tree Diagram.

- a. Place the central goal/issue card to the left of a flip chart or table. (The remainder of the instructions will assume that cards are being used, but the same steps would apply if the chart is drawn directly on the flip chart.)
- b. Ask the question, "What method or task do we need to complete in order to accomplish this goal or purpose?" Find the ideas on the cards or flip chart list that are most closely related to that statement. These may also be viewed as those tasks that are the closest in terms of sequence or cause and effect.
- c. Place the ideas/tasks from "b" immediately to the right of the central issue card as you would in a family tree or organizational chart.
- d. The ideas/tasks from "c" now become the focal point. In other words, the question from "b" is repeated and the remaining cards are again sorted to be placed to the right as the next row in the tree. This process is repeated until all of the cards or recorded ideas are exhausted.

Note: If none of the cards answer the repeated question, create a new card and place it in the proper spot.

- e. Review the entire Tree Diagram to ensure that there are no obvious gaps in sequence or logic. Check this by reviewing each path, starting at the most basic task to the extreme right. Ask of each idea/task, "If we do Y, will it help lead to the accomplishment of this next idea/ task?"
- f. Review with other groups for relevant input and revise where needed.

5.0 Matrix Diagram

5.1 Definition

This tool organizes large groups of characteristics, functions, and tasks in such a way that logical connecting points among each are graphically displayed. It also shows the importance of each connecting point relative to every other correlation.

Of the tools discussed thus far (KJ Method, Interrelationship Digraph, System Flow/Tree Diagram), the Matrix Diagram has enjoyed the widest use. It is based on the principle that whenever a number of items are placed in a line (horizontal) and other items are placed in a row (vertical), there will be intersecting points that indicate a relationship. Furthermore, the Matrix Diagram features highly visible symbols that indicate the strength of the relationship among the items that intersect at that point. The Matrix Diagram is very similar to the other tools, in that new, cumulative patterns of relationships emerge based on the interaction between individual items. Even in this most logical process, unforeseen patterns just happen.

5.2 When to Use the Matrix Diagram

Because the Matrix Diagram has enjoyed the widest use of the new tools, it has evolved into a number of forms. The key to applying a Matrix Diagram successfully is choosing the right format matrix for the situation. The following are the most commonly used matrix forms.

5.3 Matrix Diagram Shapes

The most basic form of Matrix Diagram is the L-shaped diagram. In the L shape, two interrelated groups of items are presented in line and row format. It is a simple, two-dimensional representation that shows the intersection of related pairs of items as shown in Figure C-4. The Matrix Diagram may be used to display relationships among items in countless operational areas such as administration, manufacturing, personnel, and R&D. There are also matrices in the shape of Ts, Ys, Xs, and Cs for comparing various types and numbers of information sets.

			A				B			
			1	2	3	4	5	6	7	8
1	1.1	1.11								
		1.12								
	1.2	1.21								
		1.22								
2	2.1	2.11								
		2.12								
		2.13								
	2.2	2.21								
		2.22								

Figure C-4. Matrix Diagram.

5.4 Matrix/Tree Diagram Relationships

Generating the most complete set of items possible is as important as selecting the right matrix shape. The Tree Diagram is widely used to generate the tasks, ideas and/or characteristics that form one or more sides of a matrix.

Figure C-4 also shows how two tree diagrams have been merged into a simple L-shaped matrix. The tree diagrams might represent a set of tasks to be accomplished (vertical axis of matrix) and the departments/functions of an organization (horizontal axis). The degrees of responsibility of each task can then be clearly allocated and indicated.

5.5 Construction of a Matrix Diagram

The process of constructing any of the various forms of Matrix Diagrams is very straightforward.

1. Generate the two, three, or four sets of items that will be compared in the appropriate matrix.

Note: These often emerge from the last row of detail in a Tree Diagram. This is the most effective method, but the matrix has proven helpful when based upon brainstormed items from a knowledgeable team.

2. Determine the proper matrix format. The choice of sets of items to compare is based on an educated guess, experience, and trial and error. Don't be afraid to abandon or modify a line of reasoning.
3. Place the sets of items in such a way as to form the axes of the matrix. If these items come from one or more Tree Diagrams, you can simply tape the cards (if used) on a flip chart pad. Otherwise, you can simply record the items directly on the pad. Finally, draw the lines that will form the boxes within which relationship symbols will be placed.

4. Decide on the relationship symbols to be used. The following are the most common, but use your imagination.

- Function Responsibility Chart

P - Primary Responsibility

S - Secondary Responsibility

T - Tertiary Responsibility (should receive more information)

- Quality Characteristics Chart

A - Most Critical

B - More Critical

C - Critical

- Product Testing Chart

- - Test in Process

O - Test Scheduled

X - Test & Evaluation Possible

Note: Regardless of which symbols you choose, be sure to include a legend that prominently displays the relationship symbols and their meanings.

6.0 Matrix Data Analysis

6.1 Definition

Matrix Data Analysis is accomplished by arranging data displayed in a Matrix Diagram so that it can be more easily viewed to reveal the true strength of the relationships among variables.

6.2 When to Use Matrix Data Analysis

Matrix Data Analysis is primarily used for market research, planning, development of new products, and process analysis. It is used to determine the representative characteristics of each variable being examined. For example, what are the demographic characteristics of groups of people who like or dislike certain foods? What are the representative characteristics of a new cloth given an array of possible end uses.

6.3 Construction of a Matrix Data Analysis Diagram

1. In order to find the “representative characteristics” of a product or consumer, use the “Principal Component Analysis Method.” This is a formula that mathematically calculates the impact of a factor on a process.
2. Compare data among evaluation groups showing how much of the intergroup variation is due to a particular characteristic of that group.
3. Calculate the cumulative contribution rates of the principle components to the overall ratings.
4. Display the distribution of results graphically in a four-quadrant chart.

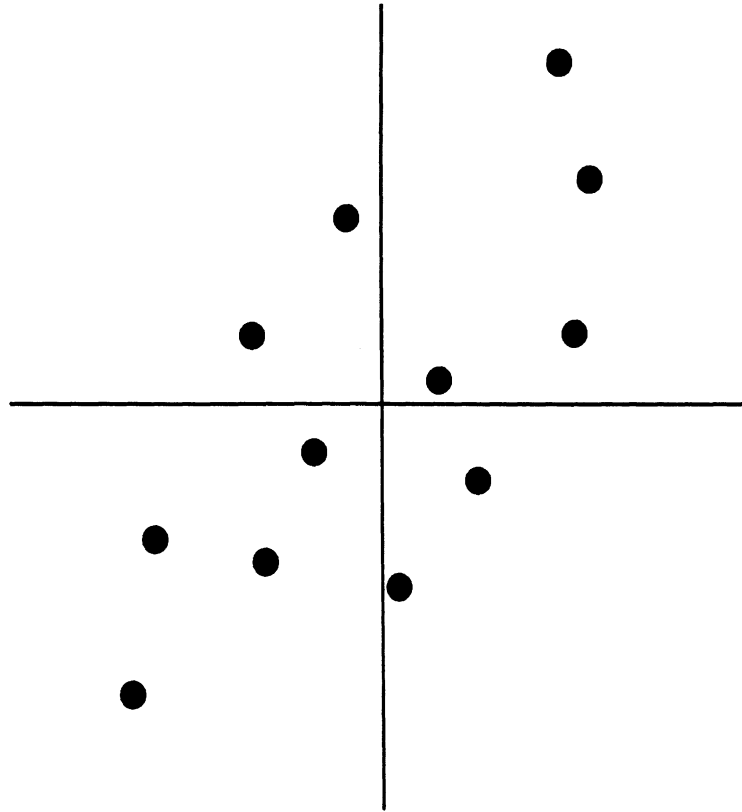


Figure C-5. Matrix Data Analysis.

7.0 Process Decision Program Chart (PDPC)

7.1 Definition

Process Decision Program Chart (PDPC) is a method that maps out every conceivable event and contingency that can occur when moving from a problem statement to possible solutions. This tool is used to plan each possible chain of events that needs to occur when the problem or goal is an unfamiliar one. The underlying principle behind the PDPC is that the path toward virtually any goal is filled with uncertainty.

PDPC anticipates the unexpected and, in a sense, attempts to short circuit the cycle so that the check takes place during a dry run of the process. The beauty of PDPC is that it not only tries to anticipate deviations, but it also facilitates development of countermeasures that will either

- a. prevent the deviation from occurring, or
- b. be in place in case the deviation occurs.

The first option is ideal in that it is truly preventive. However, we live in a world of limited resources. In allocating these resources we have to often play the odds as to the chance of X, Y, or Z happening. Given that fact, the next best thing is to have a contingency plan in place for a situation that occurs when we are betting against the odds. PDPC provides a structure to support both prevention and reaction.

7.2 When to Use a Process Decision Program Chart

PDPC is like the Tree Diagram in structure and aim, since both deal with possible patterns of methods and plans. In the same vein, it is closely tied to methods in reliability engineering such as Failure Mode & Effective Analysis (FMEA) and Fault Tree Analysis (FTA).

The prime difference between these two types of Process Decision Program Charts is that FMEA starts from the smallest detail (subsystem) and assesses the probability of failure at any step. Also, it determines the cumulative impact on the end goal. FTA, on the other hand, starts with an undesirable result and then traces it back, sequentially looking for the cause. PDPC is enjoying widespread use in particular because of the stress on product liability.

7.3 Construction of a Process Decision Program Chart

Even though the construction of a PDPC is a methodical process, it has few guidelines in terms of the process and finished product. The most important thing to keep in mind is that you must get to the point where deviations and contingencies are clearly indicated. This must be true at every level of detail in the chart.

Note:

The goal statement that starts the PDPC process often emerges from tools such as the KJ, Interrelationship Digraph, or even the Tree Diagram. As is true of all the other tools, PDPC can also be used effectively on its own.

One word of caution: The creation of possible paths and countermeasures can multiply the complexity of the chart tremendously. Don't let it overwhelm you. Break the material into bite-sized pieces, develop each piece, and then reassemble the final product.

The following seems to be the most workable approach:

- a. Follow the instructions for the Tree Diagram through to the end.
- b. Take one branch of the Tree Diagram (starting from the purpose in the row to the immediate right of the ultimate goal/purpose) and ask the questions: What could go wrong at this step? or What other path could this step take?

Note: It is easier if the items in that original branch are on cards so that they can be moved easily. This is important because you are inserting problems and countermeasures into an existing sequence.

- c. Answer the questions in "b" by branching off the original path.
- d. Off to the side of that step, list actions or countermeasures that could be taken. These are normally enclosed in "clouds" similar to cartoon captions and attached to that problem statement.
- e. Continue the process until that original branch is exhausted.
- f. Repeat "b" through "e" on the next most important tree branch, etc.

- g. Assemble the individual branches into a final PDPC, review with the proper team of people, and adjust as needed.

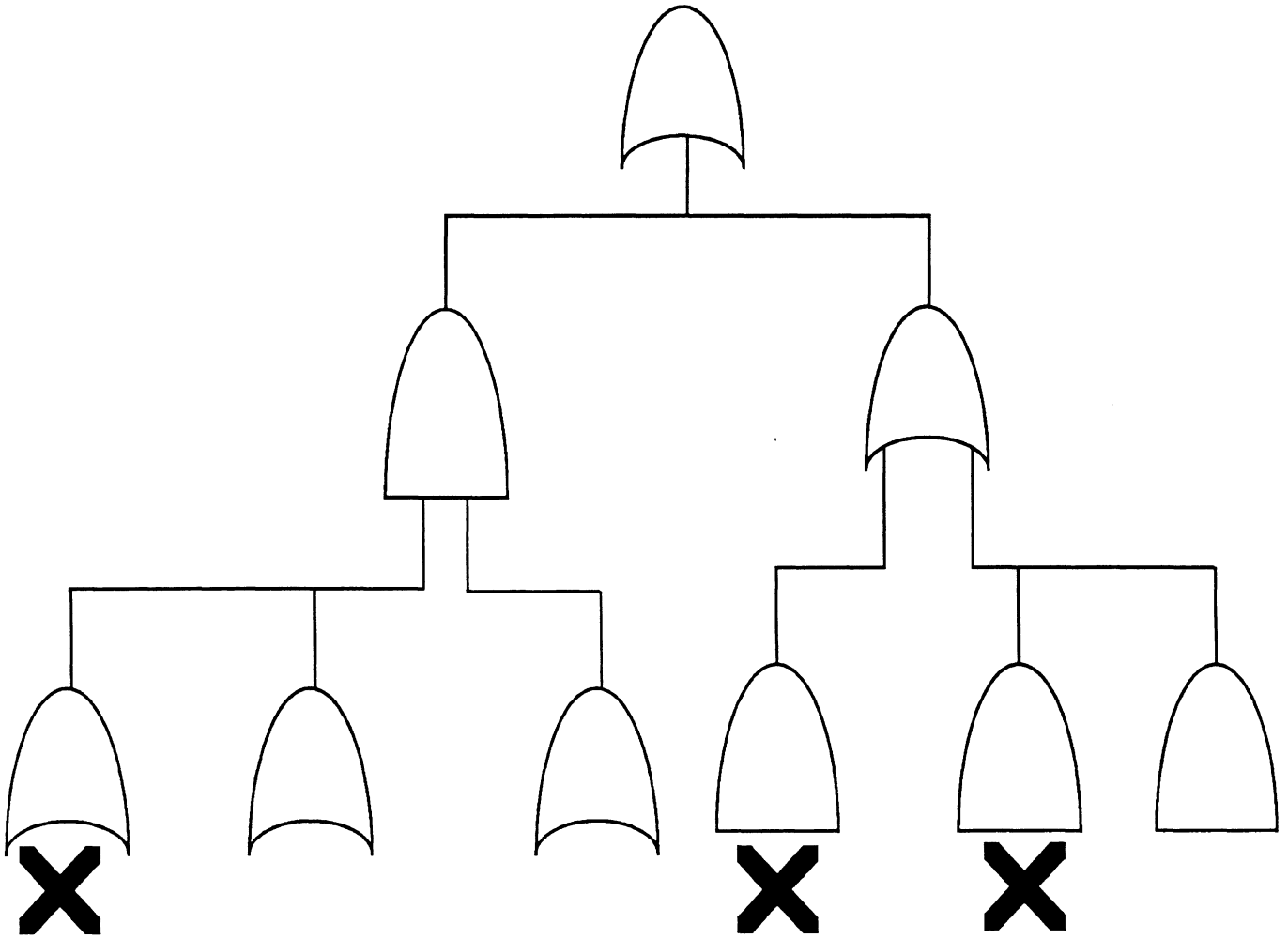


Figure C-6. Process Decision Program Chart.

8.0 Arrow Diagram

8.1 Definition

This tool is used to plan the most appropriate schedule for any task and to control tasks effectively as they progress. This tool is closely related to the CPM and PERT Diagram methods. It is used when the task at hand is a familiar one with subtasks that are of a known duration.

The arrow diagram is based on the Program Evaluation and Review Technique (PERT), which was developed in the United States during the 1950s to aid the development of the U.S. Navy's Polaris Missile program. The Arrow Diagram removes some of the magic from the traditional PERT process. This is consistent with the general idea that the key to Japanese success is their ability to take previously available tools and make them accessible to the larger population. So, instead of industrial, manufacturing, and design engineers papering their walls with PERT charts, they can be used as a daily tool throughout the organization.

8.2 When to Use the Arrow Diagram

The most important criterion is that the subtasks, their sequencing, and their duration must be well known. If this is not the case, then the construction of the Arrow Diagram can become a very frustrating experience. When the timing of the actual events is very different from the Arrow Diagram, people dismiss the Arrow Diagram as a nuisance, never to be used again. When there is a lack of process history, the PDPC is usually a much more helpful tool.

Note:

Do not be afraid to admit that you may not know everything there is to know about a process. It is better to decide on the proper tasks and sequencing than to pretend that you have a handle on the scheduling dimension.

Obviously, there are many processes that do have a well documented history. Therefore, the Arrow Diagram has enjoyed widespread use in such areas as:

- New Product Development
- Construction Project Control
- Marketing Planning
- Complex Negotiations

8.3 Construction of an Arrow Diagram

As usual, a successful process is based on having complete input from the right sources. It is possible that one person could have all of the needed information for structuring an Arrow Diagram, but it is highly unlikely. Therefore, assembling a team of the right people is the first step. This team would follow the steps listed below.

1. Generate and record all the necessary tasks to complete the project.
2. Determine the interrelationships between the tasks (what precedes, follows, or is simultaneous to each task), placing them in the proper flow. Delete duplications and add new tasks if jobs are overlooked.
3. Once these paths between tasks are established, write in the nodes, number them, and add arrows between tasks in each path and between paths as necessary. Each task is made up of two nodes. The task that begins with node #1 and ends with node #2 is task 1,2.
4. Carefully study the number of days, hours, weeks, etc. and calculate the earliest and latest start time for each node.

The use of an Arrow Diagram is necessary to calculate the Critical Path (from Critical Path Method), which is the longest cumulative time that the tasks require. This is, therefore, the shortest time in which one could expect the final tasks to be completed.

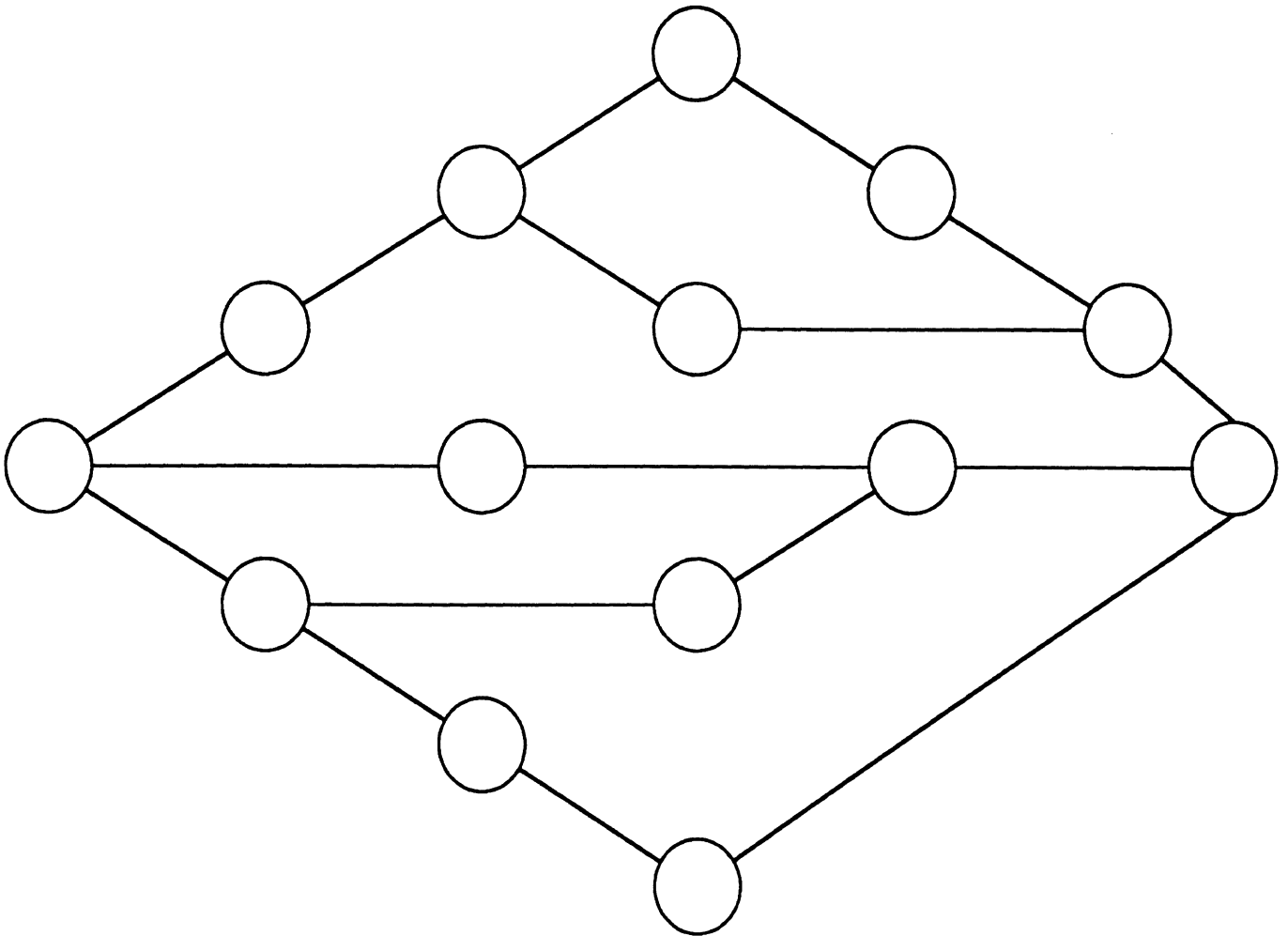


Figure C-7. Arrow Diagram.

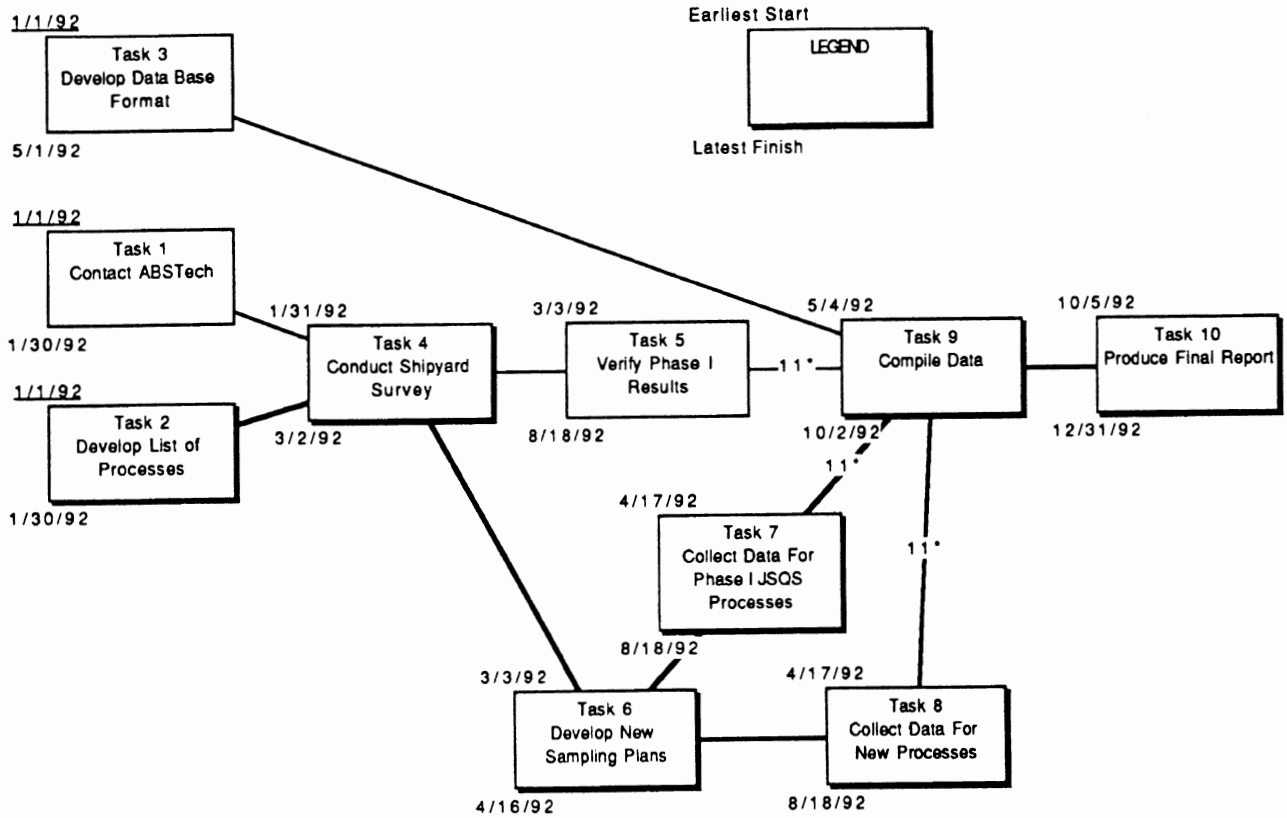


Figure C-8. CPM Network Diagram.

Appendix "D"

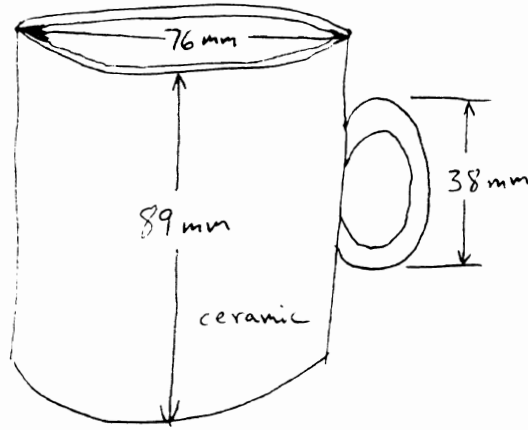
Basic OFD Example:
"Captain's Coffee Cup"

QFD Example: "Captain's Coffee Cup"

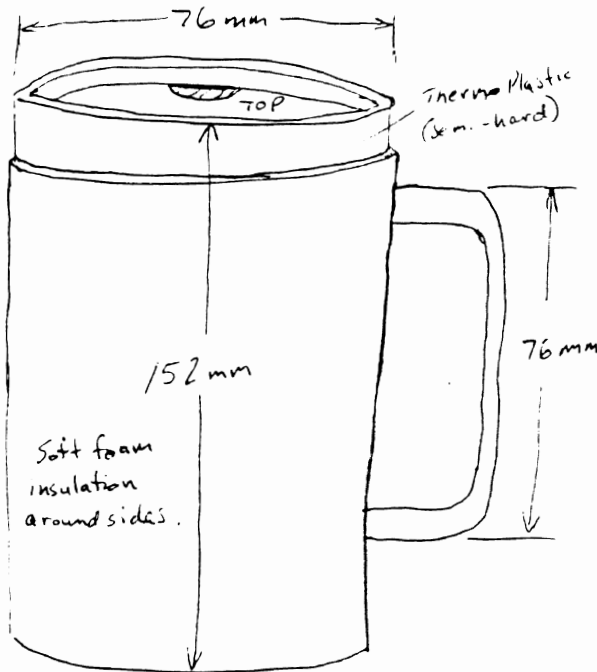
Customer: People who use cups for drinking on boats.

Project Focus Area: Create best cup for use on a boat.

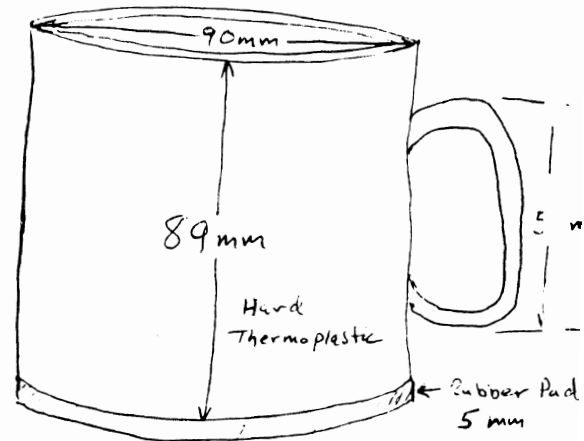
Time Constraint: 6 months from start of product development to market.



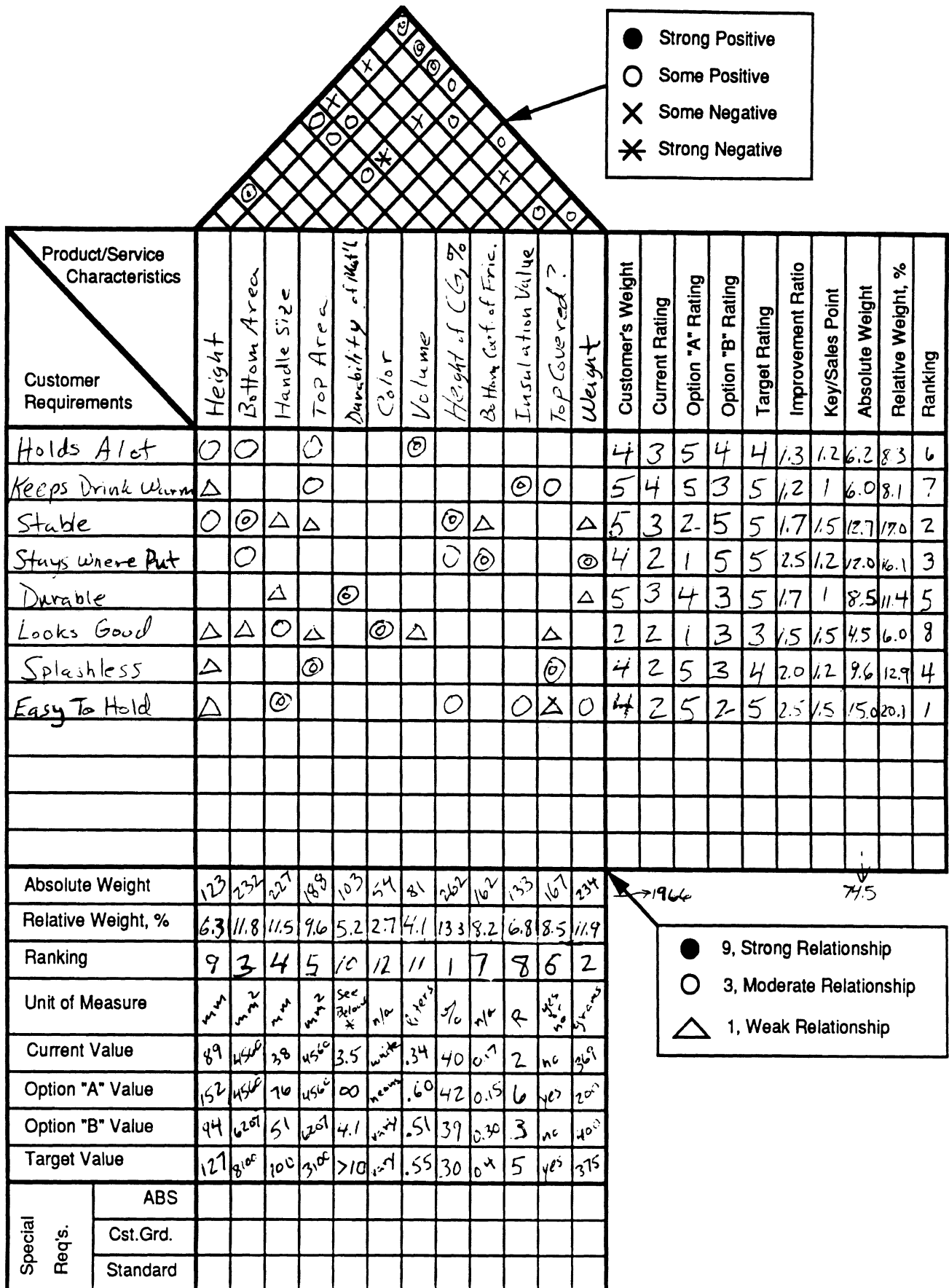
Current Cup



Competitor "A"



Competitor "B"



* Height from which a 10mm steel ball is dropped causing permanent damage to the cup. (in meters)

Product Planning Matrix.

Interim Product/ Part Characteristics			Captain's Coffee Cup											
			Cup Body			Cup Handle			Cup Bottom		Cup Top			
Important Product/Service Characteristics	Target Value	Relative Weight	Mat'l. Type	Bottom Thickness	Height	Bottom Diameter	Opening Height	Opening width	Thickness	Mat'l. Type	Thickness	Bottom Surface Finish	Mat'l Type	Thickness
			Height of CG, %	30	13.3	⊙	⊙						○	△
Bottom Area, mm ²	800	11.8				⊙								
Handle Size, mm	100	11.5			○		⊙	⊙	○					
Top Area, mm ²	3100	9.6			△	○								
Top Covered, yes or no	yes	8.5											⊙	⊙
Bottom Coef. of Fric.	.4	8.2								⊙		⊙		
Weight	375	11.9	⊙				○	○	○	○	○		○	○
Insulation Value, R	5	6.8	⊙							○	○		○	○
Absolute Weight			169	120	164	135	139	139	70	170	69	74	173	146
Relative Weight			10.7	7.7	10.5	8.6	8.9	8.9	4.5	10.8	4.4	4.7	11.0	9.3
Target Value			6	124	100	95	25	13		3				3

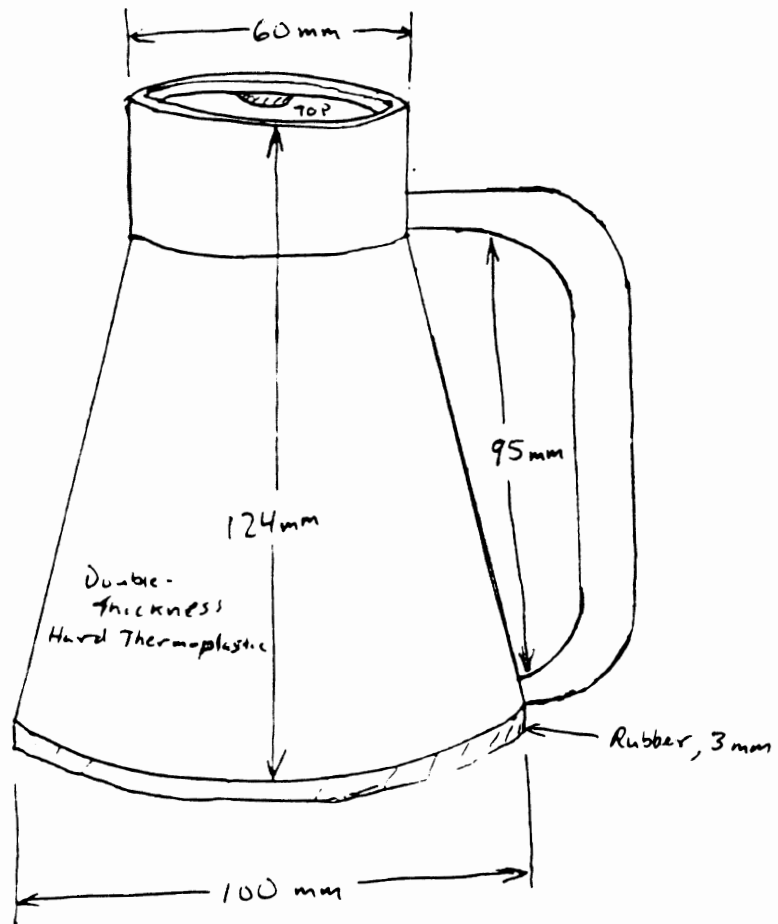
● 9, Strong Relationship
 ○ 3, Moderate Relationship
 △ 1, Weak Relationship

=1567
 → Decisions on material types are important.

Hard Thermo-Plastic

Rubber
 25 diameter per cm²
 5.5 for thermo plastic

Product Design Matrix.



New Cup

Appendix B

QFD Instructor's Manual

QUALITY FUNCTION DEPLOYMENT

Instructor's Manual

The National Shipbuilding Research Program

QUALITY FUNCTION DEPLOYMENT

Instructor's Manual

The National Shipbuilding Research Program

QUALITY FUNCTION DEPLOYMENT

Instructor's Manual

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QUALITY FUNCTION DEPLOYMENT

Instructor's Manual

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QUALITY FUNCTION DEPLOYMENT

Foreword

The Quality Function Deployment (QFD) project was initiated by the National Shipbuilding Research Program (NSRP) to research and demonstrate methods of customer-driven planning for total quality shipyard operations.

This QFD material was developed, and associated workshops were presented, for the NSRP by the University of Michigan Transportation Research Institute, Marine Systems Division. The background research was conducted by Prof. Howard Bunch, NAVSEA Professor of Ship Production Science and project director, and Mr. Mark Spicknall, Senior Engineering Research Associate. The User's Manual, Instructor's Manual, and case studies were initially developed by Mr. Spicknall and graduate research assistant Mr. John Senger. As a result of feedback from workshop participants, the manuals and case studies were later revised by Prof. Bunch, Mr. Spicknall, research scientist Roger Horne, RAdm. U.S. Navy (ret.), and graduate research assistants Mr. David Amble and Mr. John Immink.

Some of this material was developed directly from commercially available courses and other material on Quality Function Deployment from the following sources:

Technicomp, Inc., 1111 Chester Avenue, Cleveland, Ohio 44114-3516, (800-735-4440). Videotapes from Technicomp have been used with permission as one of the major features of the NSRP QFD course. A copy of these tapes can be borrowed from the NSRP Documentation Center along with an Instructor's Manual and a User's Manual. It is illegal to duplicate these video tapes. Anyone interested in purchasing a copy of the video tapes should contact Technicomp, Inc.

GOAL/QPC, 13 Branch Street, Methuen, MA 01844 (508/685-3900). GOAL/QPC facilitated a QFD workshop at Portsmouth Naval Shipyard to help kick off this project, and to assist Portsmouth Naval Shipyard in its quality improvement efforts. Several references are made in this manual to GOAL/QPC's "Matrix of Matrices" approach to QFD. Additionally, sections of the appendices are excerpts from the GOAL book, Better Design in Half the Time: Implementing Quality Function Deployment, by Bob King.

American Supplier Institute, Incorporated, Six Parklane Boulevard, Suite 411, Dearborn, MI 48216 (313/336-8877).

Florida Power and Light (FP&L) - Quality Improvement Department, P.O. Box 14000, Juno Beach, FL 33408-0420, 305-552-4421. The primary project researchers attended an excellent TQM workshop presented by FP&L. FP&L's actual "House of Quality" provided a good reference for developing this material.

When material was used without modification, permission was obtained from the appropriate sources.

INSTRUCTOR'S INTRODUCTION TO THE QFD COURSE

This is the *Instructor's Manual* for the NSRP Course/Workshop in Quality Function Deployment. This guide is made up of notes for the instructor, along with all material presented in the *QFD User's Manual*. The instructor's notes will be in this font, while the *QFD User's Manual* material will be in this font. *User's Manual* page numbers will be shown underlined in the right margin where the user's pages begin; *Instructor's Manual* page numbers will be shown at the top of each page.

Course Materials

Following is a list of the materials that you will need to conduct this course:

- *QFD Instructor's Manual*
- *QFD User's Manuals* for all course participants
- Five Technicomp Video Tapes: Units 1-4 and "Case History"
- VCR (VHS format) and video monitor/TV
- Overhead Projector
- Flip charts with markers
- Large (3" X 5") Post-its™
- Masking Tape

Note: The Technicomp Video Tapes must NOT be reproduced. Technicomp, Inc. has generously given the NSRP permission to loan these video tapes from the NSRP Documentation Center Library in conjunction with the teaching of this course. If copies of the video tapes are desired, they must be purchased directly from Technicomp, Inc., 1111 Chester Ave., 300 Park Plaza, Cleveland, Ohio 44114, 1-800-255-4440.

BEGINNING OF QFD INSTRUCTION

Welcome and Introductions.

Course Objectives (Intro. Overhead).

- The primary objective of this course is to introduce those associated with ship marketing, design, construction, and shipbuilding management to Quality Function Deployment, the process by which customer requirements are translated into specific action plans for the supplier organization.
- A secondary objective is to give potential shipbuilding-related users experience with the specific mechanics of the QFD process. For any user, the process of creating the first product planning matrix is extremely difficult. This course provides participants with this experience in a workshop environment in which they can take the time to learn the process. As a result, they will find the QFD process easier when they first attempt to do a real-life QFD project within their own organizations.
- Another objective is to provide course participants with the necessary QFD background within a shipbuilding context. By using shipbuilding related case studies as the core of the course, participants should be able to facilitate and implement QFD within the shipbuilding industry more easily.
- A final objective of this course is to provide participants with QFD references, and additional QFD information and instruction.

Course Outline/Schedule and Facilities

Following is a suggested course outline and schedule. Time durations are only estimates; actual time required for each portion of the course may vary. It is suggested that the sections be taught in the order presented. It is also suggested that the course schedule and facilities be reviewed with the class at this time.

Course Outline

<u>DAY 1</u>	<u>Start</u>	<u>Duration</u>
Welcome and Introductions	8:30	0:20
Course Objectives		
Course Schedule		
Overview of Facilities		
<u>Section I</u>		
Preview of Tape #1, Overview of QFD	8:50	0:05
Viewing of Tape #1	8:55	0:30
Discussion of Basic QFD Concepts	9:25	0:30
Break	9:55	0:15
Preview of Case Study Tape, Rockwell	10:10	0:05
Viewing of Case Study Tape	10:15	0:20
Discussion of Case Study Tape	10:35	0:20
Review of Material Covered Thus Far	10:55	0:15
Lunch	11:10	12:10
<u>Section II</u>		
Preview of Tape #2, The House of Quality	12:10	0:10
Viewing of Tape #2	12:20	0:40
Affinity & Tree Diagrams, House of Quality	1:00	0:25
Break	1:25	0:15
<u>Case Study #1, Section V</u>		
Shipbuilding Case Study #1 For Entire Class		
Establishment of QFD Procedural Ground Rules	1:40	0:15
Creation of Customer Requirements, Product/Service Requirements	1:55	1:30
Break	3:25	0:15
Interpretation of the House of Quality	3:40	0:30
Relationships of Customer Requirements and Product Requirements, Degrees of importance of individual Customer Requirements, Importance weights for individual Product Requirements, Competitive Advantages, High priority customer requirements, Correlation Matrix		
Overview of Case Study #1 and Day 1	4:10	0:50
Adjourn	5:00	
<u>DAY 2</u>		
Review of Day 1	8:00	0:30

Section III

Preview of Tape #3, The Voice Of The Customer	8:30	0:10
Viewing of Tape #3	8:40	0:25
Discussion of Tape #3	9:05	0:15

Break	9:20	0:15
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Demonstration of the Voice Of The Customer Table	9:35	0:30
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Detailed Case Studies Begin, Section V

Shipbuilding Case Studies For Individual Teams	10:05	12:00
--	-------	-------

Creation of QFD Teams,
Review of QFD Procedural Ground Rules,
Review of individual shipbuilding case studies by each team,
Representation of Voices Of The Customer by team members,
Creation of Voice Of The Customer Table

Lunch	12:00	1:00
-------	-------	------

Customer Requirements and Product Requirements,	1:00	3:30
---	------	------

Creation of the House of Quality/Product Planning Matrix,
Interpretation of the information in the House Of Quality

Review of Day 2	4:30	0:30
-----------------	------	------

Adjourn	5:00	
---------	------	--

DAY 3

Review of Day 2	8:00	0:30
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Section IV

Preview of Tape #4, The Phases of QFD	8:30	0:05
Viewing of Tape #4	8:35	0:35
Discussion of Tape #4	9:10	0:20

Break	9:30	0:15
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Section V, Detailed Case Studies Complete

Continuation of Individual Team Case Studies	9:45	1:45
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Completion of House of Quality/Product Planning Matrix
Creation of a Product Design Matrix
Creation of a Process Planning Matrix
Creation of a Process Control Planning Matrix

Course Wrap-Up and Evaluations	11:30	0:30
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End Of Workshop

SECTION I: BASIC CONCEPTS OF QUALITY FUNCTION DEPLOYMENT

Section I Objectives (Overhead #1):

- Define QFD.
 - Briefly discuss the history of QFD and its origins in the shipbuilding industry.
 - Discuss benefits that have been realized through the use of QFD.
 - Discuss the QFD process and the various approaches.
 - Provide an overview of prerequisites for QFD success.
- 1) **Preview Tape #1:** This tape gives a general overview of QFD, its history, benefits, and the QFD process, and begins to get into some details of the product planning matrix.
 - 2) **Play Tape #1.**
 - 3) **Once the tape is finished, thoroughly cover the following material which is included in the *User's Manual*. Use the associated overheads that are provided. Then proceed with instructions at the end of this section.**

I. BASIC CONCEPTS OF QUALITY FUNCTION DEPLOYMENT

Pg. 1

Overhead #2

Definition of Quality Function Deployment (QFD)

Pg. 2

QFD is a disciplined planning process that facilitates the identification and deployment of customer wants and needs throughout a company as a basis for product planning, development, and implementation. QFD provides a system in which the voice of the customer drives product planning, product design, process planning, process control planning, production, sales, and service.

In the QFD context, the "customer" is anyone who uses your goods or services: a ship owner who uses a ship that you build, an engineer who uses your ship design, a mechanic who uses your work instructions, and the purchasing department who uses your material specifications could all be your customers. QFD can be used to address the needs of any of these external or internal customers.

In the QFD context, the word "quality" has a different meaning than the traditional definition, "conformance to requirements." In the parlance of QFD, the word "quality" refers to those attributes that customers want or need in the product or service of a supplier. These attributes are sometimes referred to as "customer requirements," "demanded quality," or "quality requirements." Using the QFD methodology these "customer requirements" can be deployed throughout the supplier's organization and used as the foundation for defining the products and, necessarily, the internal functions of that organization.

Overhead #3

The History Of QFD

Pg. 2

The QFD methodology was conceived and first used as a formal discipline at Kobe Shipyard of Mitsubishi Heavy Industries in 1972. Since that time QFD has been adopted by most world-class product and service suppliers as part of the Total Quality Management (TQM) philosophy (**Overhead #3A**). Some U.S. companies that have made QFD an integral part of doing business are Motorola, Ford, Rockwell International, and IBM.

Overhead #4

QFD Benefits

Pg. 3

There is overwhelming evidence that major improvements result from the use of QFD. Below is a list of benefits reported by organizations that have utilized QFD.

- Enhances internal and external communications
- Improves quality
- Increases customer satisfaction
- Reduces product development time by 30-50%
- Lowers start-up costs by 20-60%
- Reduces the number of design changes by 30-50%
- Reduces warranty claims by 20-50%
- Fosters cross-function team building
- Facilitates simultaneous product and process design
- Improves design for production
- Allows lower pricing because of lower development costs
- Removes bottlenecks in product development/implementation
- Builds a database for future product development

- Provides a means of evaluating your competition
- Identifies key areas in product development where time and effort can be focused to gain competitive advantages

QFD Terminology

At this point it will be important for the instructor to point out the differences in terminology between the different approaches to QFD. Following are the necessary terminology equivalencies. These are also provided on Overhead #5. The underlined terminology will be used in this course.

House of Quality (generic) = Product Planning Matrix (generic) = A-1 Matrix (GOAL/QPC)

Customer Requirements (NSRP) = Quality Requirements (Florida Power and Light, FP&L) = Demanded Quality (Akao and GOAL/QPC) = Required Quality (American Supplier Institute, ASI)

Product/Service Characteristics (NSRP) = Technical Requirements (Technicomp) = Quality Elements (FP&L) = Quality Characteristics (Akao and GOAL/QPC) = Quality Items (ASI)

Interim Product/Part Characteristics (NSRP) = Part Characteristics (Technicomp) = Mechanisms and Unit Parts (Akao)= Systems and Unit Parts (ASI) = Mechanisms, Systems, Sub-Systems, Parts, Components, Raw Material (GOAL/QPC)

Process Control Characteristics (NSRP) = Process Control Methods (Technicomp)

The QFD Process

Overhead #6; refer class to Figure 2, the House Of Quality, and Figure 3, the Matrix of Matrices, in the User's Manual as necessary when discussing the following topics.

The QFD process that will be the focus of this course is illustrated in Figure 1. Following are brief descriptions of individual process steps.

Defining a QFD Project

QFD is best applied to a specific need, i.e. to a specific area for which improvement or breakthrough is required or desired. In this regard, it is best to define a QFD project in the context of

- one customer or market segment,
Possible Customers- ship owner, OPNAV, production engineers, shipyard mechanics, purchasing department, etc.
- one product or service area where improvement is desired, and
Possible Products/Services- a ship, a drawing, a sub-assembly, a bill of material, blasting service, a work package, etc.
- one point in time.
Examples- at ship delivery, at beginning of detailed design, at fabrication start, at erection, at first overhaul, etc.

For example, a commercial shipbuilder may have identified that the buyers of new very large crude oil carriers (VLCCs) want significant reductions in fuel costs without a sacrifice in performance by 1994. The identification of a specific customer, a specific product need, and a specific time will allow this shipbuilder to carry out a well focused QFD project. QFD can be used for the development or improvement of any type of product or service, including manufacturing, construction, software development, or customer service for external or internal customers.

The Voice of the Customer

The voice of the customer is the foundation of QFD. The customer's voice represents the wants, needs, desires, and requirements that are deployed throughout an organization to be used as the basis for product development and implementation. The voice of the customer is actually a

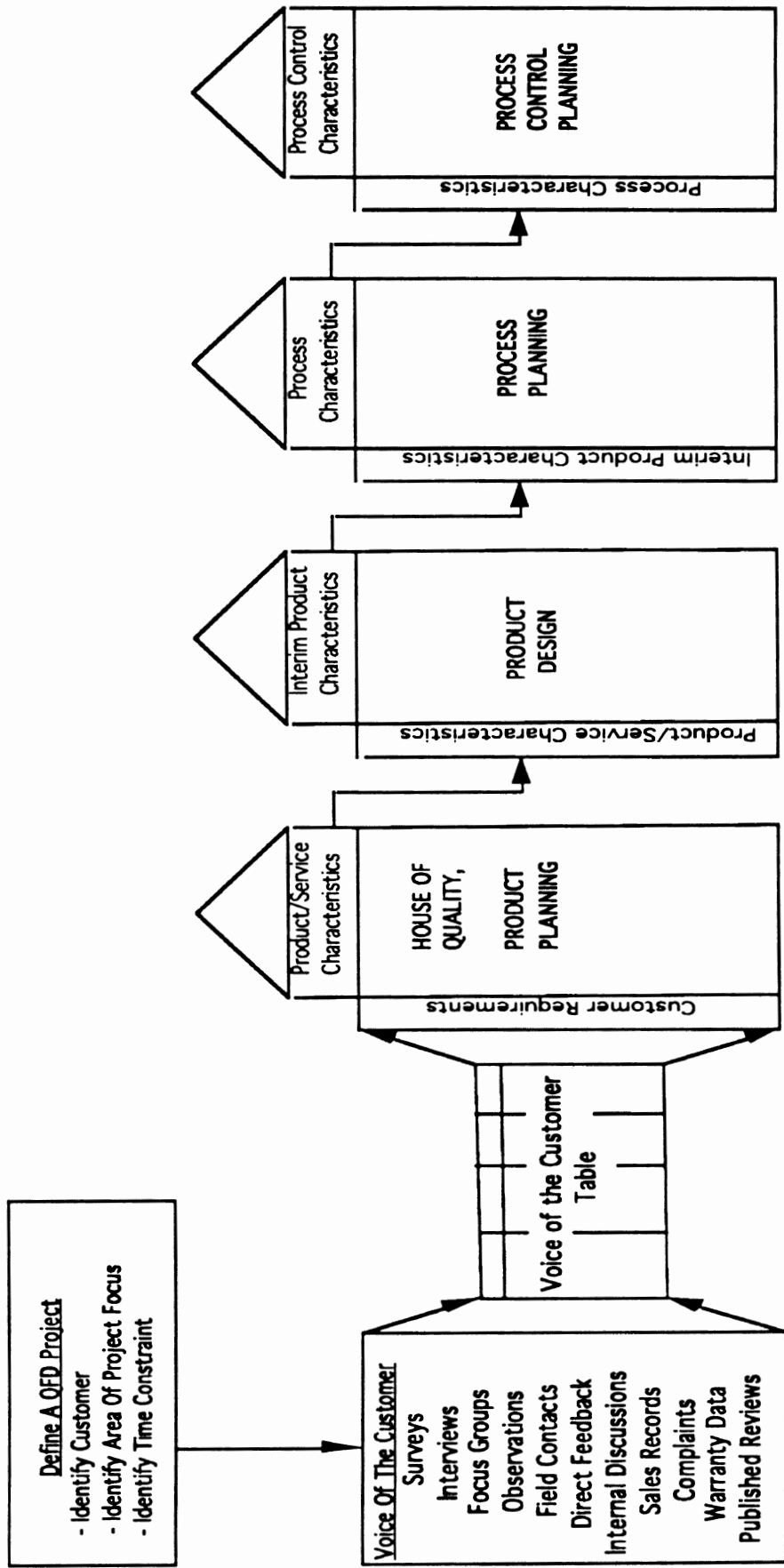


Figure 1. The Four-Matrix QFD Process.

conglomeration of many customer voices gathered from questionnaires, surveys, interviews, claims information, observations, etc., and represents only an approximation of the customers' requirements. Obviously, this approximation will be more accurate and complete if a large quantity of quality information is available and organized in a rational manner. A tool called the Voice of the Customer Table (VOCT) is used to organize this information into specific, positive, singular customer requirements. The detailed examination and organization of the voice of the customer will be the subject of Section III.

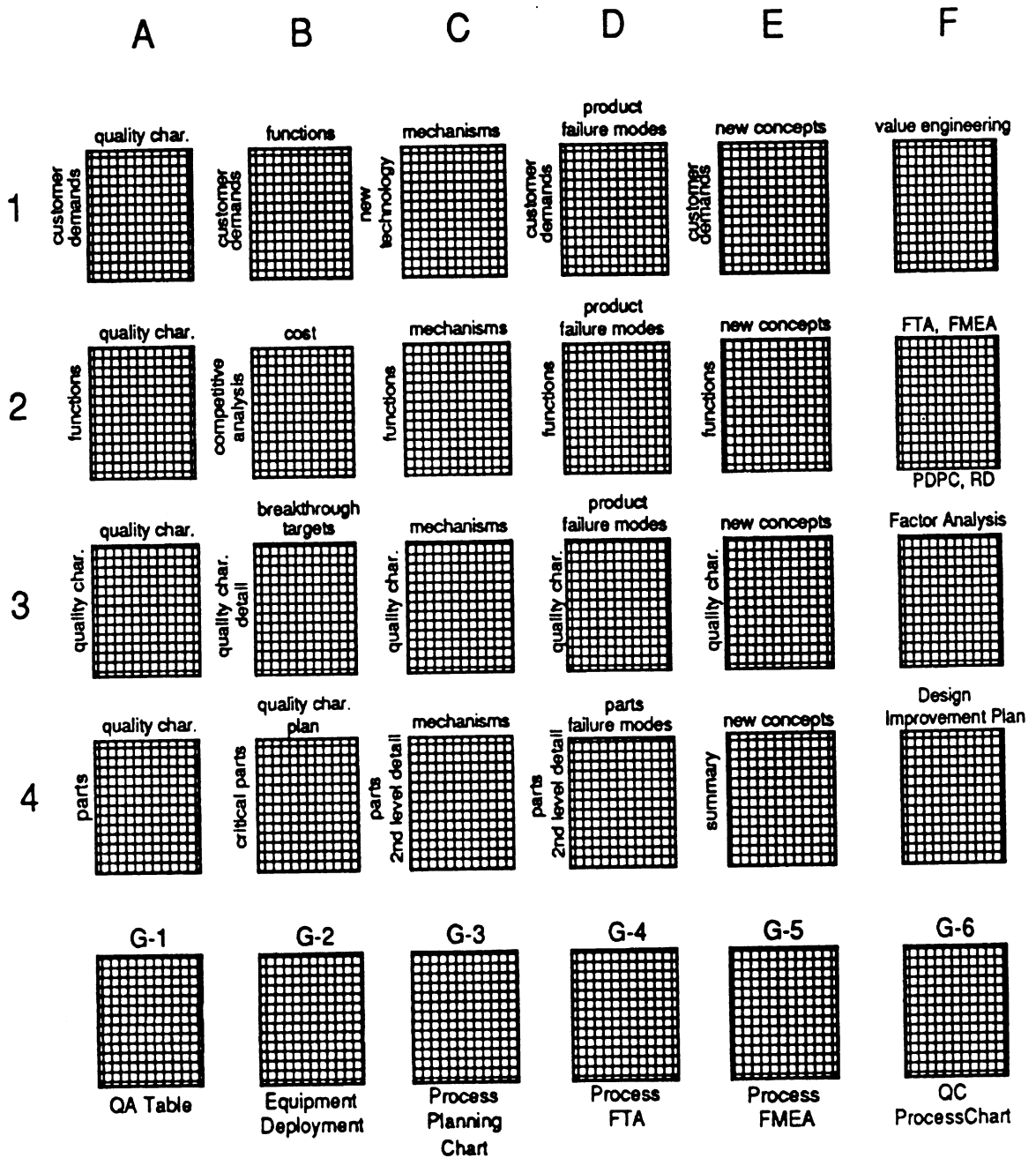
The "House of Quality", Product Planning Matrix, or A-1 Matrix

The "House of Quality," Product Planning Matrix, or A-1 Matrix shown in Figure 2, is used to begin to translate the customer's requirements into the technical language of the supplier's organization, to identify relationships between customer requirements and the product/service characteristics that can be affected by the supplier, to prioritize these customer requirements and potential supplier action areas, and to identify the relative strengths and weakness of alternative products/competitors. The detailed development of the "House of Quality" will be the subject of Section II.

Further Product Development and Implementation

From the "House of Quality" a number of other matrices can be developed for various purposes. Bob King of GOAL/QPC developed the "Matrix of Matrices" in Figure 3, which consists of an additional 29 matrices that can be used for everything from product failure mode analysis to prioritizing new product concepts relative to customer requirements. This course will focus on a simplified four-matrix QFD approach shown in Figure 1.

It is important to note that QFD is completely flexible with regard to the matrices that are appropriate for a specific project. QFD users may even develop matrices that are not a part of the approach shown in Figure 1 or part of the "Matrix of Matrices" if there is a need.



Source: GOAL/QPC

Figure 3. The Matrix of Matrices.

Overhead #7

Requirements For QFD Success

Pg. 9

1. Management commitment for at least a QFD pilot project is a minimum requirement.
2. Active support and participation of management is ideal.
3. Project team diversity is essential. The team may include members from:
 - Strategic Planning
 - Marketing
 - Design/Engineering
 - Process Engineering
 - Production Engineering
 - Production
 - Quality Assurance

Depending on the type of QFD project, the team might also include:

- Purchasing
 - Distribution
 - Accounting
 - Finance
 - Human Resources
 - Suppliers
 - Customers
4. Project team members must have a basic understanding of QFD and must be committed to the QFD process.

Have course participants discuss the product development processes used by their organizations and how these processes differ from QFD.

- **How does marketing do its job? Where do they get their information, and how do they use it? How do they identify and prioritize potential customers and products, or product features?**
 - **How do specific departments identify and prioritize the important characteristics of the products/services they must provide to other departments?**
 - **How does marketing communicate with design?**
 - **How do marketing and design communicate with industrial engineering, manufacturing engineering, production engineering, production control, and production during product development?**
- 4) Preview "Case Study" Tape: This tape describes how Rockwell International used QFD to develop a specific product. Ask the class to pay particular attention to what the project participants say about the requirements and benefits of the QFD process.**
- 5) Play Case Study Tape.**
- 6) Once the tape is finished, discuss the tape, answer any questions, and briefly review the objectives of this session and the material covered thus far.**
- **Rockwell made a time and resource commitment to the QFD process.**
 - **Rockwell provided QFD training for employees at all levels of the organization.**
 - **Their QFD team members had diverse backgrounds.**
 - **They focused on a specific area where improvement was desired.**
 - **They improved communication with external customers, internal personnel, and suppliers.**
 - **They increased productivity in product development.**

Section I Objectives (Review)

SECTION II: THE HOUSE OF QUALITY

Section II Objectives:

- Describe the tools that are useful for creating QFD matrices.
 - Explain each part of a product planning matrix.
 - Describe how a completed product planning matrix can be analyzed.
 - Explain the QFD Prerequisites at the beginning of Section V, and then use Case Study #1 to teach participants how to use affinity diagrams and tree diagrams to create a product planning matrix.
- 1) Explain to workshop participants that detailed analysis of the voice of the customer will be discussed after first discussing the House of Quality in detail so that participants will already have a sense of overall direction when they begin to analyze the voice of the customer in Section 3 and in the detailed case studies.
 - 2) Preview Tape #2: This tape describes the product planning matrix in detail. Again, point out that there will be some minor differences in terminology. The tape emphasizes the need to focus on one customer at a time, the need to think like a customer, and the need to verify the customer requirements developed and the completed matrix with others.
 - 3) Play Tape #2.
 - 4) Once the tape is finished, thoroughly cover the following material which is included in the *User's Manual*. Use the associated overheads that are provided.
 - 5) Once this material has been covered in detail, discuss the QFD Prerequisites outlined at the beginning of Appendix A, and then assist workshop participants in the development and analysis of a product planning matrix for Case Study #1. Instructor's guidelines for this work are provided at the end of this section.

II. THE HOUSE OF QUALITY

Pg. 10

Initial Tools

Pg. 1

Three of TQM's "Seven Management Tools" (see Appendix C) are used to help create the "House of Quality" and many of the other QFD matrices. These tools are the affinity diagram, the tree diagram, and the matrix diagram. The application of affinity diagrams and tree diagrams to QFD is discussed below.

Overhead #8

The Affinity Diagram

As the name implies, the affinity diagram is used to collect ideas such as customer requirements or related product characteristics developed from group brainstorming into similar groups. Each group is then given a heading to describe or summarize its contents. See Figure 4.

Overhead #9

Example: Your customer is the shipyard mechanic. This is a list of your customer's requirements for a shipbuilding work package:

- Bill of material
- Any special tools required
- Complete work sketches
- Definition of global reference lines to be used
- All material for production of the interim product
- All necessary production control documentation
- Accurate pieces
- Accurate list of material
- All pieces with proper ID
- All necessary inspection documentation
- Accurate work instructions
- Proper reference lines or marks on all pieces
- Work sketches without unneeded information

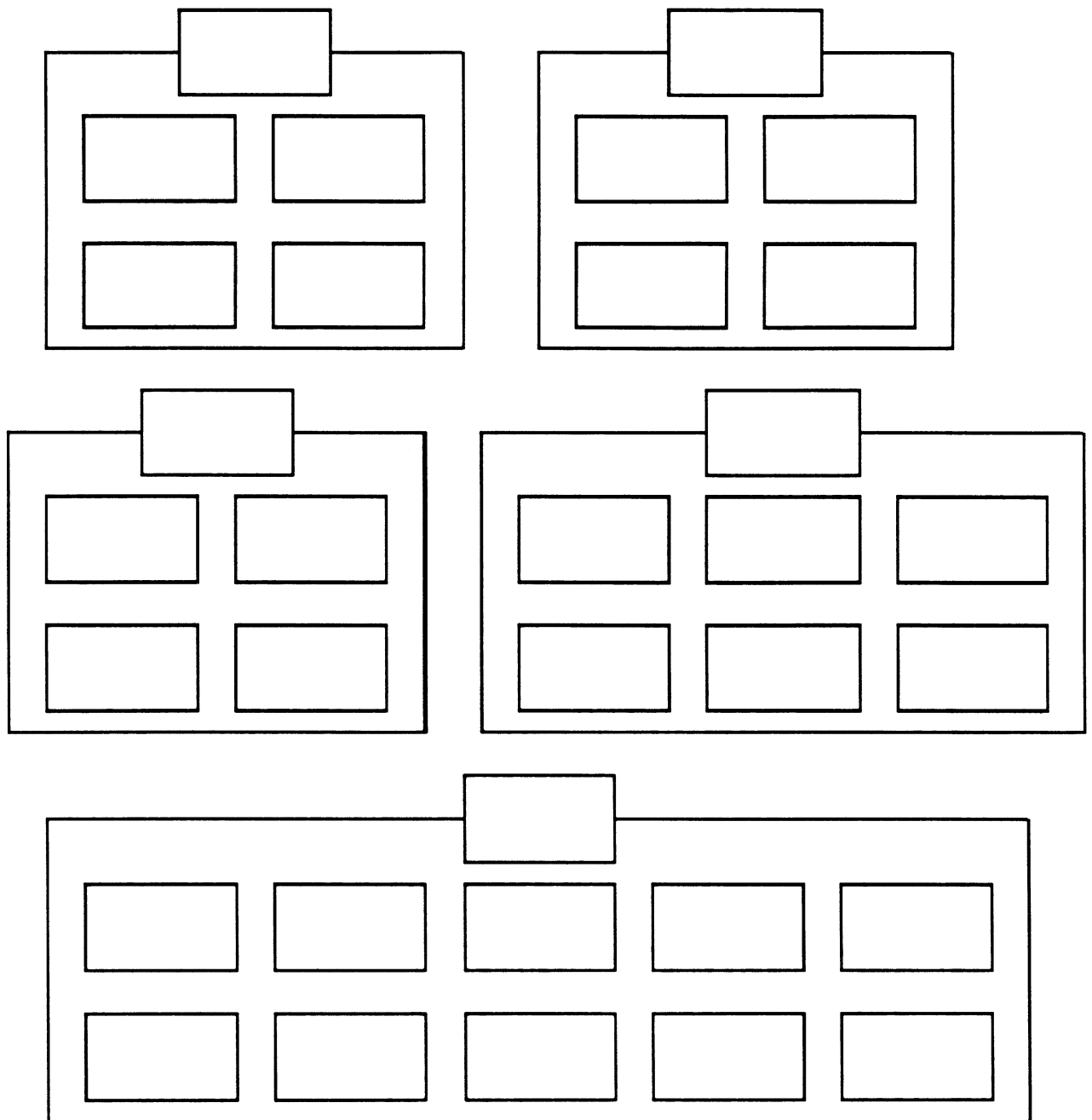


Figure 4. Affinity Diagram.

These customer requirements might be grouped in an affinity diagram as follows:

Overhead #10

- Correct Parts
 - All material for production of the interim product
 - Accurate pieces
 - All pieces with proper ID
 - Proper reference lines or marks on all pieces
- Correct Bill of Material
 - Accurate list of material
 - Any special tools required
- Correct Instructions and Sketches
 - Complete work sketches
 - Definition of global reference lines to be used
 - Accurate work instructions
 - Work sketches without unneeded information
- Correct Work Documentation
 - All necessary production control documentation
 - All necessary inspection documentation
- Correct Tools
 - Any special tools required

Notice that some customer requirements fall into more than one group. This is possible and acceptable. What is important is that the requirements are organized into a framework that allows them to be addressed logically.

Less Detailed, More Important - - - - - ▶ More Detailed, Less Important

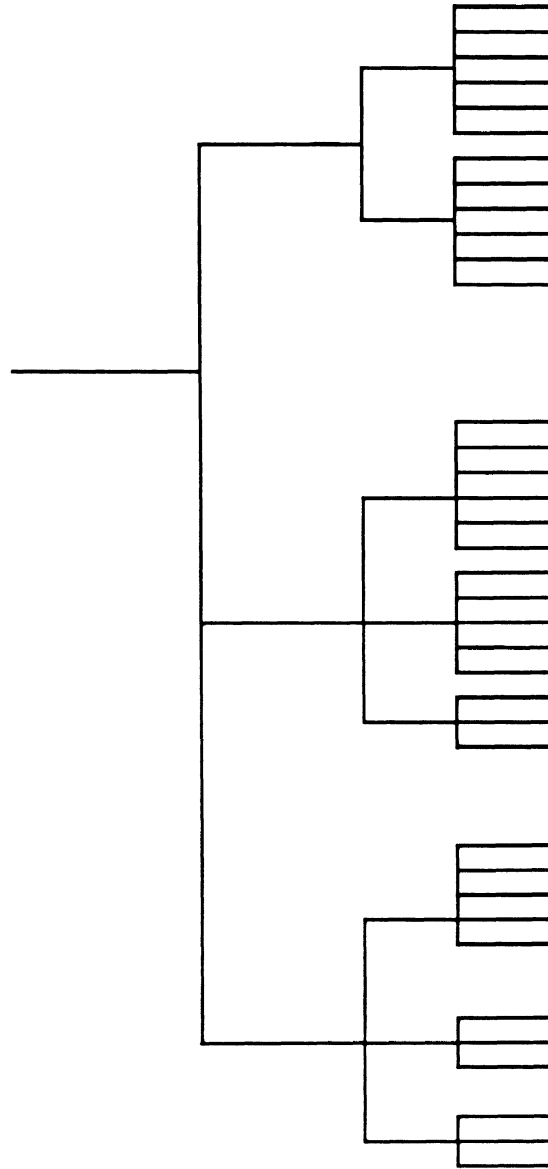


Figure 5. Tree Diagram.

Once the tree diagram is complete, a particular level of detail can be selected for use along an axis of a QFD matrix. Figure 6 illustrates how tree diagrams are used in the creation of a QFD matrix.

Overhead #13

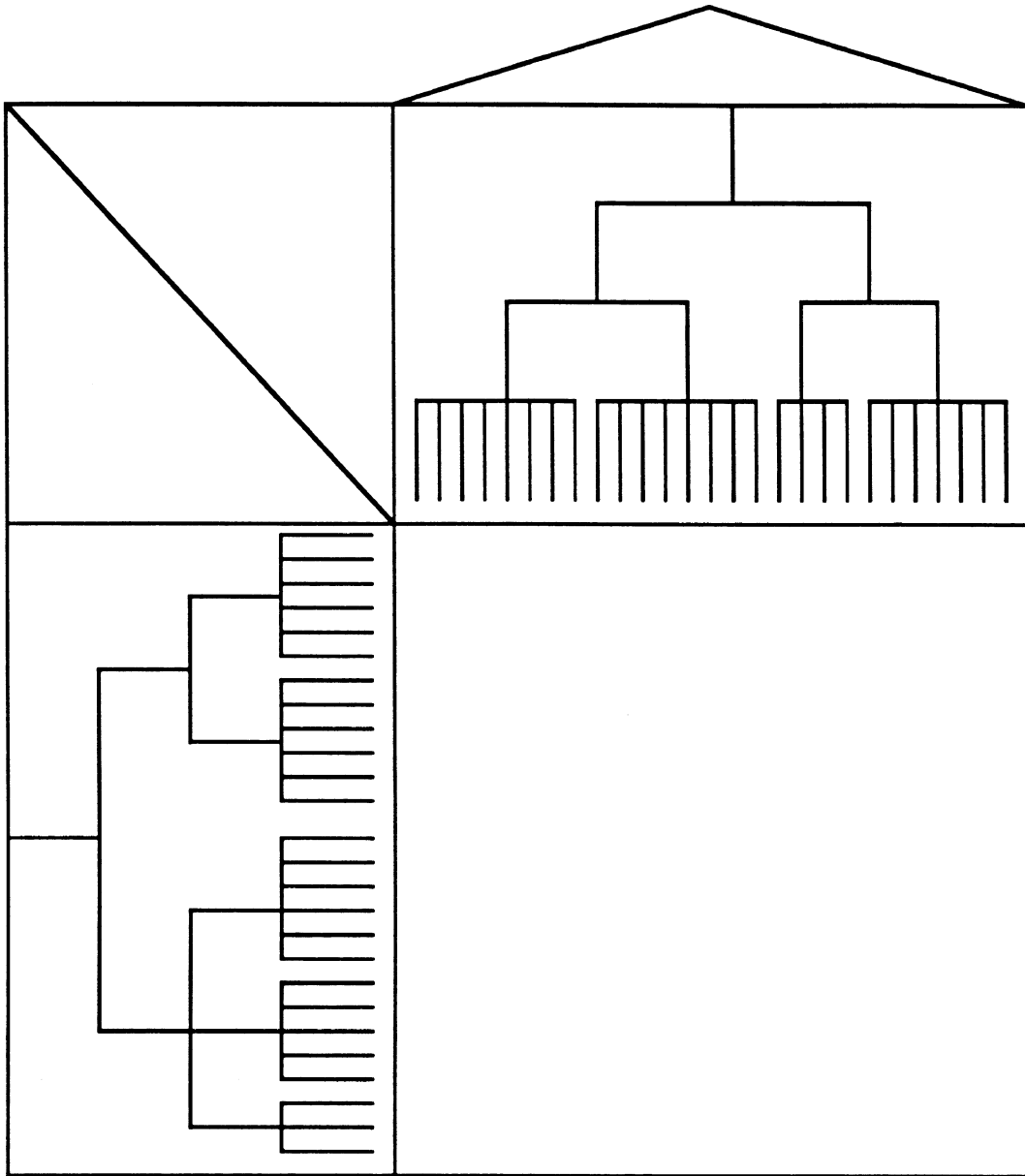


Figure 6. Tree Diagrams Related To A QFD Matrix.

Overhead #14

Figure 7 shows a product planning reference matrix with sections labeled from **A** to **W**. Following are detailed descriptions of each section of the House Of Quality.

A- Customer Requirements, The Customer's World

1. Surveys, observations, direct feedback, brainstorming, etc. are used to identify customer wants and needs.
2. Customer requirements are singular, positive statements of need. Customer requirements must not include numbers or words that refer to areas that are addressed by other QFD matrices, such as function, interim product characteristics, or process characteristics.
3. An affinity diagram is used to group these wants and needs into logical categories.
4. A tree diagram is used to establish the relationships between, and importance of, customer wants and needs, and to help assure that the list of wants and needs is complete.
5. A particular level of detail from the tree diagram is then chosen for representation of the customer requirements in the product planning matrix.

B- Product/Service Characteristics, The Supplier's World

1. Product/service characteristics are the measurable and controllable things the supplier can affect to address customer requirements. Product characteristics are developed by brainstorming for each customer requirement: "How can we, the supplier, address this customer need?" Or, more specifically: "What things about our product (or service) can we, the supplier, affect to address this specific customer need?"
2. Product/service characteristics must not include references to customer requirements or to areas that are addressed by other QFD matrices.
3. An affinity diagram is used to group the things the supplier can affect into logical categories.

4. A tree diagram is used to establish the relationships among, and importance of, these things the supplier can affect, and to help assure that the list is complete.
5. A particular level of detail from the tree diagram is then chosen for representation of the product/service characteristics in the product planning matrix.

C- Relationship Matrix

1. The relationship matrix is used to identify how strongly specific product/service characteristics affect or control individual customer requirements.
2. Different symbols are used to represent the strengths of relationships:
 - =strong relationship=9
 - O=moderate relationship=3
 - Δ=weak relationship=1
 - blank=no relationship=0
3. The numerical values associated with the different types of relationships are used to calculate the absolute weights of product/service characteristics (see **N**).

D - Customer's Weight

1. The customer's weight is a number between 1 and 5, determined by the project team to reflect the relative importance of each customer requirement to the customer. This judgment is based on "voice of the customer" information.

1=not very important to customer; 5=extremely important to customer

E, F, G- Ratings of Ability to Meet Customer Requirements

1. **E** is a set of ratings from 1 to 5 that reflect how well the current product/service meets each customer requirement.
2. **F** and **G** are ratings from 1 to 5 that reflect how alternative product/service options, perhaps those of competitors, currently meet customer requirements. These other products/services must be known well enough to allow objective rating.

1= does not meet requirement very well; 5=meets requirement extremely well

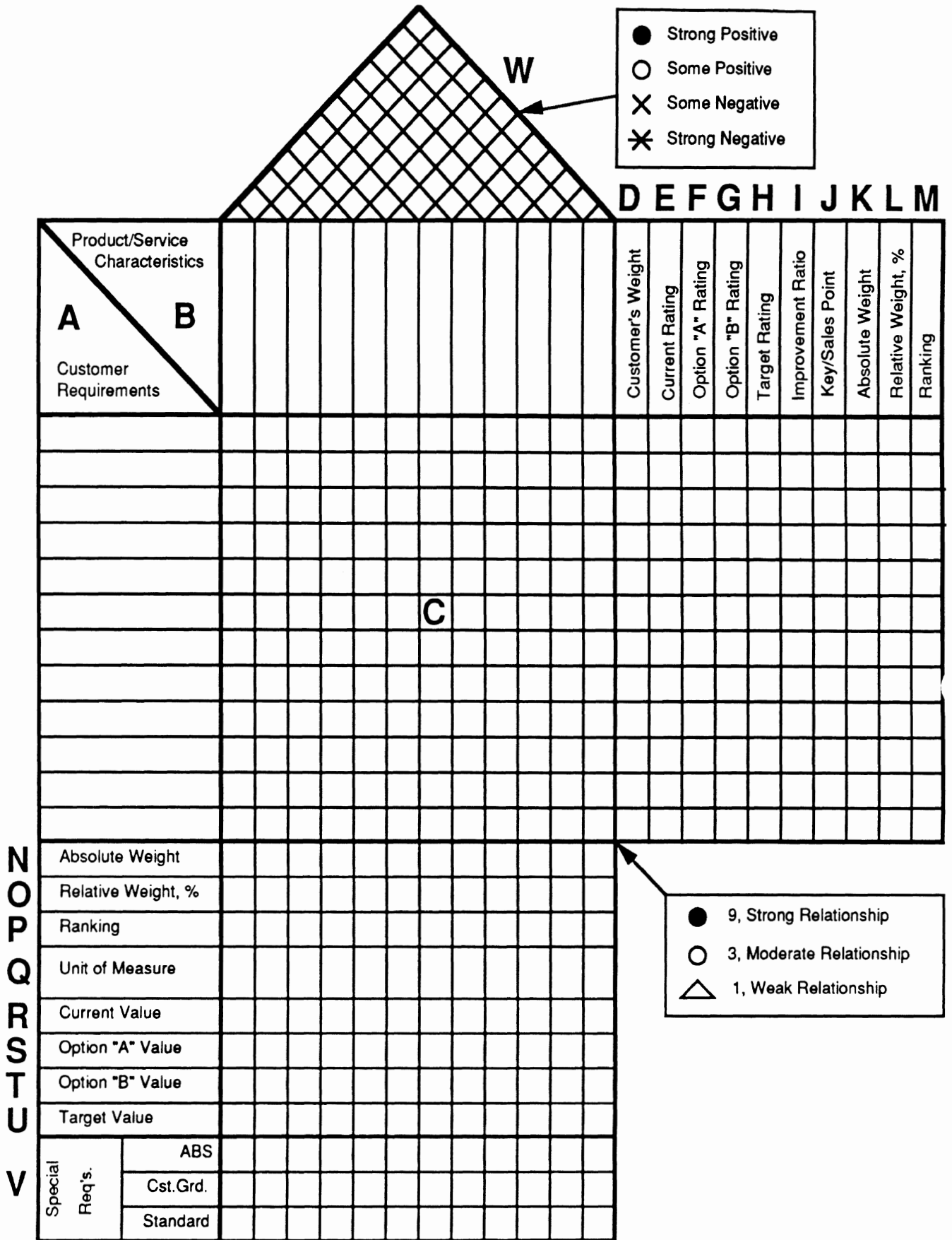


Figure 7. House Of Quality/ Product Planning Reference Matrix.

H - Target Rating

1. Target ratings are from 1 to 5 and reflect the goals of the supplier organization for satisfying each customer requirement.

I - Improvement Ratio

1. The improvement ratio for each customer requirement reflects what percent change is required over the current rating, **E**.
2. This ratio is calculated for each customer requirement as target rating divided by current rating, **H/E**.

J - Key or Sales Point

1. Key points or sales points identify those customer requirements that could have a significant impact on customer satisfaction and sales.
2. Customer requirements with a high customer weight are often key or sales points. Also, customer requirements that are considered new or exciting could be key or sales points.
3. Major key or sales points are given a value of 1.5. Minor key or sales points are given a value of 1.2. All other customer requirements are given a key or sales value of 1.

K - Absolute Weight of Customer Requirements

1. This absolute weight quantifies the overall importance of each customer requirement.
2. $K = D \text{ (Customer's Weight)} * I \text{ (Improvement Ratio)} * J \text{ (Sales Point)}$

L - Relative Weight of Customer Requirements

1. The relative weight of each customer requirement expresses the absolute weight of each customer requirement relative to the total absolute weights of all customer requirements in terms of a percentage.
2. $L = 100 * K \text{ (Absolute Weight)} / \sum K \text{ (Sum Of All Absolute Weights)}$

M - Ranking of Customer Requirements

1. Rankings simply present the order of importance of the customer requirements based upon their relative weights.

N - Absolute Weight of Product/Service Characteristics

1. This absolute weight quantifies the overall importance of each product/service characteristic by accounting for the relationships between each individual product/service characteristic and all customer requirements.
2. $N = \sum [C \text{ (Relationship Matrix Score)} * L \text{ (Relative Weight)}]$

O - Relative Weight of Product/Service Characteristics

1. The relative weight of each product/service characteristic expresses the absolute weight of each product/service characteristic relative to the total absolute weights of the other product/service characteristics in terms of a percentage.
2. $O = 100 * N \text{ (Absolute Weight)} / \sum N \text{ (Sum Of All Absolute Weights)}$

P - Ranking of Product/Service Characteristics

1. Rankings simply present the order of importance of the product/service characteristics based upon their relative weights.

Q - Unit Of Measure

1. If a specific product/service characteristic has a unit of measure, that unit of measure is shown in this field. Example: product characteristic "length" could have a unit of measure "meters."
2. Nondimensional measures, or indices, can also be used to represent some specific types of product/service characteristics.

R - Current Value

1. If the current product/service has particular values for specific product/service characteristics, these values are shown in these fields.

S, T - Option Values

1. These values show the product/service characteristic values of alternative products/services options, perhaps those of competitors.

U - Target Value

1. Target values reflect the goals of the supplier organization for each important product/services characteristic.
2. Target values can be based on what competitors are achieving, on experimentation, on research, etc.
3. Target values must agree with the chosen units of measure. They must be measurable, and project team members must agree on how target values will be measured.

V - Special Requirements

1. Special requirements are those things that must be considered during product planning that represent the requirements of customers other than the primary customer identified, such as regulatory agencies and the organization itself.
2. Special requirements are identified at the product planning stage to assure that they are addressed throughout the entire product development process.

W - Correlation Matrix

1. The correlation matrix is used to identify product/service characteristics that are related in synergistic or conflicting ways. A synergistic relationship means that, as one product/service characteristic is moved toward its desired target, it forces another product/service characteristic to also move toward its target. A conflicting relationship means that, as one product/service characteristic is moved toward its desired target, it forces another product/service characteristic to move away from its target.
2. Conflicting relationships between product/service characteristics identify that design and development compromises will be required in these areas.

3. Different symbols are used to represent the strengths of relationships.

- =strong synergistic relationship
- O=moderate synergistic relationship
- X=moderate conflicting relationship
- *=strong conflicting relationship
- blank= no relationship

Now discuss the QFD Prerequisites outlined at the beginning of Section V, and then assist workshop participants in the development and analysis of a product planning matrix for Case Study #1.

Instructor's guidelines for Case Study #1:

- Present the QFD Prerequisites provided at the beginning of Section V to workshop participants.
- Split workshop participants into two teams.
- Have the teams pick leaders and decide upon the rules that they will use during this QFD case study.
- Have the teams fill in the left axis of the product planning matrix with the customer requirements provided.
- Have team members brainstorm product characteristics associated with each customer requirement. Have them write each of these product characteristics on a Post-it™.
- Have team members create affinity and tree diagrams to organize the product characteristics for inclusion along the top axis of the product planning matrix. To create an affinity diagram have team members write each product characteristic on a Post-it™ and then have them group the Post-its™ with similar characteristics. Remember that a single product characteristic can belong in more than one group; if this is the case, have the team duplicate the characteristic and put it wherever they feel it belongs. Once these groups of characteristics have been created, they must be labeled. Then the groups can be moved to create a tree diagram based on the hierarchy of, and relationships between groups of ideas. Make sure that teams discuss and resolve internal differences of opinion in an orderly way.

- Have team members develop the remainder of the product planning matrix as outlined in the instruction beginning on page 17 of the User's Manual and page 25 of the Instructor's Manual.
- Discuss how to analyze a product planning matrix using the material provided below.

Analysis of a Product Planning Matrix

Once a product planning matrix has been completed, it is important to check certain attributes of the matrix for completeness, level of detail, and consistency.

1. A blank row in the relationship matrix may indicate that a product/service characteristic has not been identified to address that specific customer requirement. **Overhead #15**
2. A blank column in the relationship matrix may indicate that an unimportant product/service characteristic has been identified, or that a particular customer requirement has been inadvertently ignored. **Overhead #16**
3. If an important customer requirement has no strong relationship with any product/service characteristic, additional product/service characteristics should be defined that strongly affect that customer requirement. **Overhead #17**
4. If several customer requirements have identical relationships with product/service characteristics, these customer requirements probably need to be broken down to another level of detail for analysis in the product planning matrix. **Overhead #18**
5. If there are many weak relationships identified between customer requirements and product/service characteristics, these relationships should be examined in more detail. **Overhead #19**
6. If the relationships identified form a diagonal line through the relationship matrix, customer requirements may contain the language of the product/service characteristics (from the supplier). This is an indication that more emphasis must be placed on the voice of the customer, as opposed to the voice of the supplier, when defining customer requirements. **Overhead #20**
7. If most of the relationships identified between customer requirements and product/service characteristics form a small distinct block somewhere within the relationship matrix, both customer requirements and product/service characteristics associated with this area of the matrix should be broken down to another level of detail. **Overhead #21**

8. If a single product/service characteristic has relationships with nearly all of the customer requirements, the product/service characteristic may need to be broken down to another level of detail, or this product/service characteristic should be reviewed to assure that it does not include references to interim product characteristics, process characteristics, process control requirements, or other information that is accounted for in other QFD matrices.

Overhead #22

9. If a single customer requirement has relationships with nearly all product/service characteristics, the customer requirement may need to be broken down to another level of detail, or the customer requirement may specify interim product characteristics, process characteristics, process control requirements, or other information that is accounted for in other QFD matrices.

Overhead #23

10. If your product or service rates higher than the competition in meeting certain customer requirements, then it should also have better values for the associated product/service characteristics, and vice versa. **Overhead #14**

11. If there is a customer requirement that is very important to the customer but is not well satisfied by your product/service or that of your competition, then this is an area in which a major competitive advantage could be obtained if significant improvements were made in your product/service to address this requirement. **Overhead #14**

Overhead #24

Having completed a House of Quality, you should have a very good idea of the relative importance of specific customer requirements and associated product or service characteristics. You should have identified areas in which a competitive advantage might be gained, and in which compromises might have to be made in product development. You should also have developed target values for product/service characteristics, and methods for measuring whether these product/service requirements are being met.

Have representatives of each team present their matrix to the remainder of the workshop participants. Each team should be allowed 15 minutes for their presentation. Have all participants analyze each matrix during these presentations according to the guidelines outlined on page 24 of the User's Manual and page 32 of the Instructor's Manual.

SECTION III: THE VOICE OF THE CUSTOMER

Section III Objectives:

- Review material covered in Sections I and II.
 - Explain the different types/perceptions of quality.
 - Review potential sources of the voice of the customer.
 - Describe how to use the voice of the customer table.
 - Review QFD Prerequisites at the beginning of Section V, and split the group into teams and have them begin the shipbuilding related Cases Studies 2 through 5 (one case study per team), beginning with the voice of the customer. Help direct the teams in the development of each case study.
- 1) Preview Tape #3: This tape describes the process of obtaining the voice of the customer. The tape explains the importance of organizing this information-collection effort through defining specifically who the customer is, specifying what methods of information gathering will be used, and defining when and how this work will be done, and who will do it. The tape also emphasizes the importance of listening, following up, encouraging feedback, and providing some flexibility for customer response.
 - 2) Play Tape #3.
 - 3) Once the tape is finished, thoroughly cover the following material which is included in the *User's Manual*. Use the associated overheads that are provided.
 - 4) Once this material has been covered in detail, review the QFD Prerequisites outlined at the beginning of Appendix A, and then assist workshop participants in the development and analysis of a product planning matrix for Case Studies #2 through #5. Instructor's guidelines for this work are provided at the end of this section.

III. THE VOICE OF THE CUSTOMER

Pg. 26

Once a customer, a project, and a project time objective have been established, the voice of the customer becomes the foundation for the QFD project. Therefore, it is vitally important to develop as accurate an approximation of the customer's voice as possible.

Types of Product "Quality"

Pg. 27

There are three types of "quality" that should be defined through the voice of the customer. These are:

Overhead #25

One-dimensional qualities. These are features that customers specifically request. If these features are present, customers are pleased. If these features are absent, customers are not satisfied. **Examples: comfort, performance, ease of use, safety, durability, versatility, etc.**

Expected qualities. These are features that are considered essential and, therefore, are often taken for granted and not specifically requested. If these features are present, customers are satisfied. If these features are absent, customers are not satisfied. **Examples: basic functionality like turning ability, stopping ability, ability to load and unload cargo, etc.; basic resistance to corrosion (the ship will be painted).**

Exciting qualities. These are features that customers may not realize are possible. Such features may relate to new technology. Because customers do not realize that these features are possible, they do not specifically request them. If these features are present, customers are surprised and very pleased. If these features are absent, customers are not unsatisfied. **Examples: shipboard automation, significant performance advantages due to design breakthrough, etc.**

Because customers are likely to specify only one-dimensional qualities, it is important that the QFD project team has the means or knowledge necessary to identify expected and exciting qualities. To help define expected qualities, customers should be asked specifically about those qualities they consider essential. To help define exciting qualities, customers should be asked specifically about features they would like in your product if current technologies and accepted practices were not constraints.

Have class members relate some personal experiences as a customer, such as when you were purchasing a new car. Also discuss some one-dimensional (color: white), expected (floats),

and exciting (modular cargo-handling equipment) qualities that relate to ships. Give an example of a product and have workshop participants identify examples of the three kinds of quality.

Sources of the Voice of the Customer

Overhead #26

There are many potential sources for the voice of the customer. Table 1 can be used to compare these sources from the standpoint of the quality of information they provide, and the resources that are required for their utilization.

Table 1. Voice Of The Customer Sources.

	Information	Complexity	Sample	Bias	Time	Cost
INTERVIEWS						
Face to Face	Direct	Medium	Small	No	High	High
Telephone	Direct	Medium	Small	No	High	High
FOCUS GROUPS	Direct	High	Small	No	High	High
OBSERVATIONS						
Clinics	Direct	High	Small	No	High	High
Displays	Direct	High	Small	No	High	High
FIELD CONTACTS						
Sales Meetings	Direct	Low	Small	Yes	Low	Low
Service Calls	Direct	Low	Small	Yes	Low	Low
Trade Shows	Direct	High	Medium	Yes	High	High
DIRECT VISITS	Direct	High	Medium	Yes	High	Medium
EMPLOYEE FEEDBACK	Direct	High	Medium	Yes	High	Medium
SURVEYS						
Mail	Indirect	Medium	Large	Yes	High	High
Telephone	Direct	Medium	Medium	Yes	High	High
Comment Cards	Indirect	Medium	Large	Yes	High	Low
Point of Purchase	Indirect	Medium	Large	Yes	High	Low
SALES RECORDS						
Monthly Sales	Indirect	Low	Large	Yes	Low	Low
Sales Contacts	Indirect	Low	Large	Yes	Low	Low
Replacement	Indirect	Low	Large	Yes	Low	Low
Part Sales	Indirect	Low	Large	Yes	Low	Low
COMPLAINTS						
Letters	Direct	Low	Large	Yes	Low	Low
Cards	Direct	Low	Large	Yes	Low	Low
WARRANTY DATA						
Service Records	Direct	Low	Large	Yes	Low	Low
Service Workers	Direct	Low	Large	Yes	Low	Low
Return Cards	Direct	Low	Large	Yes	Low	Low
TOLL-FREE HOTLINE	Direct	Low	Large	Yes	High	High
PUBLICATIONS						
Government	Indirect	Low	Large	Yes	Low	Low
Independent	Indirect	Low	Large	Yes	Low	Low
Trade Journals	Indirect	Low	Large	Yes	Low	Low
Consumer	Indirect	Low	Large	Yes	Low	Low

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Overhead #27

Once enough information has been collected to adequately approximate the voice of the customer, this information must be organized to facilitate the conversion of the voice of the customer into specific customer requirements for the House Of Quality. A tool that can be used to help define specific customer requirements is the Voice Of The Customer Table (VOCT) shown in Figure 8. Following is a description of each column of the VOCT.

Demographics. This column is for relevant information about each individual providing a voice of the customer statement. This information can be used by the project team to weigh the validity and importance of each particular voice. For example, this column might contain information about a customer's years of experience using your particular product or service, his job responsibilities, etc.

Voice Of The Customer. This column is for statements of the customer's wants, needs, desires, or requirements in the exact words of the individuals who have provided the information.

Contextual Information. This column can be used for identifying or clarifying the context of each individual's statement about what they want in the product or service. Based on each individual's statement, this contextual information can include

- Who uses, or will use it?
- What is it used for, or could it be used for?
- When is it, or will it be used?
- Why is it, or could it be used?
- How is it, or will it be used?

Reworded Statement. This column is used to reword the voice of the customer statements so that the actual customer wants expressed in the statements are made clearer. Project team members can create several paraphrased versions of each voice of the customer statement to help develop these reworded statements.

Customer Requirement. This column is for the identification of specific customer requirements from the reworded statements. Each customer requirement must be a positive statement, must express a single requirement, must be clear to every project team member, must be traceable back to a voice of the customer statement, must be devoid of numbers, and must be devoid of words referring to function, interim product characteristics, process characteristics, and process control characteristics.¹ A single customer statement may include several customer requirements.

¹If a project team decides to use the Matrix of Matrices, then the customer requirements, or "Demanded Quality," developed for the A-1 matrix, must also be devoid of words referring to areas covered by the other 29 matrices such as cost, reliability, etc.

All Other Columns. All other columns are used to identify those elements of customer statements that refer specifically to product/service items that are addressed in matrices other than the product planning matrix. These items might include function, interim product characteristics, and process characteristics.²

Overhead #28

Once a VOCT has been completed, the project team should have a list of specific, singular customer requirements that are traceable back to specific voice of the customer statements. All project team members should have a mutual understanding of these customer requirements. These customer requirements can now be used as the basis for an affinity diagram, a tree diagram, and, finally, the customer requirement axis of the product planning matrix. The VOCT might also have captured customer-provided information, such as functional requirements, that can be referenced in creating other QFD matrices.

Instructor's guidelines for Case Studies #2 through #6:

- Review the QFD Prerequisites provided at the beginning of Section V with workshop participants.
- Split workshop participants into teams with five to ten members each. The teams should be as balanced as possible in numbers, experience, and diversity.
- Have the teams pick leaders and decide upon the rules that they will use during this QFD case study.
- Have team members play the role of the customer and add four or five customer quotes, based on their own experience, to the list of customer quotes that has been provided in their case study.
- Have team members work through the Voice Of The Customer Table as described in the preceding section, starting with their customer quotes and developing customer requirements.
- Once customer requirements have been identified, have team members develop a product planning matrix for their case study, as outlined in Section II. The instructors will have to provide the ratings (parts F and G of the product planning matrix) of how well competitors of each team are meeting the customer requirements that the team has identified; the instructors should tell each team to inform them when

²Again, if a project team decides to use the Matrix of Matrices, these other columns of the VOCT might include customer information specifically referencing function, cost, reliability, etc.

their team reaches this point in the development process.

- **Have representatives for each team present their case study development to the rest of the workshop participants once each team has completed their product planning matrix. Each team should be given 15-20 minutes for their presentation.**

SECTION IV: OTHER QFD MATRICES

Section IV Objectives:

- Explain the reasons why a project would continue beyond the development of the product planning matrix, and describe the options for continuing a project.
 - Explain the product design matrix.
 - Explain the process planning matrix.
 - Explain the process control planning matrix.
 - Explain other matrices that might be useful (function analysis and failure mode and effects analysis).
 - Assist the project teams in creating these matrices for their case studies.
- 1) Preview Tape #4: This tape describes the options available for continuing a QFD project. The four-matrix approach is described in some detail, and other matrices are described which can help support the development of the product design matrix, process planning matrix, and process control planning matrix. Explain that this tape contains a great deal of information and that individuals and/or teams will need to refer to the notes in this section, and may need to review portions of Tape #4 to gain a working understanding of this material.
 - 2) Play Tape #4.
 - 3) Once the tape is finished, thoroughly cover the following material which is included in the *User's Manual*. Use the associated overheads that are provided. Assist project teams in developing these additional matrices for their case studies.

IV. OTHER QFD MATRICES

Overhead #29

A QFD project is complete when the project team has met its objectives. Most QFD projects have not gone beyond the development of the product planning matrix. Having completed the product planning matrix, the project team will have:

Improved communication. The analysis will have provided opportunities for significant discussions with customers, and within the supplier organization.

Gained understanding of customer desires. The analysis will have provided an understanding and appreciation of the customer's wants and needs.

Established product characteristic priorities. The analysis will have resulted in an understanding of the product characteristics that are most important for meeting customer requirements.

Evaluated the competition. The analysis will have provided a better understanding of how well competitors products/services are meeting the needs of the customer.

Determined where high payoff can occur. Areas will have been identified where improvement in product/service characteristics could have a significant effect on customer satisfaction, sales, and competitiveness.

Having completed the product planning matrix, however, the project team may feel that additional detail is required in some areas, or that a detailed implementation plan is required to help translate customer demands into specific supplier organization actions.

At this point, the project team should examine the available tools for continuing the QFD process beyond the product planning matrix. It is possible to use matrices from both the four-matrix approach and the Matrix of Matrices approach, depending on what matrices are considered appropriate by the project team. This manual will continue to focus upon the four-matrix approach to QFD shown in Figure 1.³

³For more detailed instructions on the use of the Matrix of Matrices approach to QFD, refer to, Better Design In Half The Time, Implementing Quality Function Deployment In America, third edition, by Bob King, GOAL/QPC, 1989; and, Quality Function Deployment, Integrating Customer Requirements Into Product Design, by Yoji Akao of Tamagawa University, Productivity Press, Cambridge, Massachusetts, 1990.

Overhead #30

The next step in the QFD process beyond the creation of the product planning matrix is the creation of the product design matrix. The product design matrix is used to translate important product/service characteristics into necessary interim product and part characteristics. An example of the product design matrix is provided in Figure 9. Following are descriptions of each part of the product design matrix.

Important Product/Service Characteristics

The important product/service characteristics are transferred from the top axis of the product planning matrix to the left axis of the product design matrix. The target values and relative weights for each of these product/service characteristics are also transferred to the product design matrix. It may be useful for the project team to develop a Function Analysis Matrix, Figure 10, (**Overhead #31**) to assure that all important product/service characteristics have been included. A function analysis matrix has product functions identified along the left axis and the product/service characteristics from the product planning matrix along the top axis, and is completed in the same way as the product planning matrix. The resultant relationship matrix is used to identify those product/service characteristics that are important relative to product functionality. This matrix is often called "the voice of the engineer."

Interim Product/Part Characteristics

A breakdown of the product is defined from primary interim products down to specific pieces. Affinity and tree diagrams are used as necessary to help organize and prioritize these interim products. A meaningful level of interim product/part detail is selected, and the characteristics of these interim products/parts are used along the top axis of the product design matrix.

Relationship Matrix

The relationship matrix is used to identify relationships between the overall product/service characteristics and the interim product/part characteristics. The same symbols and values are used that were used in the product planning matrix.

Absolute Weight, Interim Product/Part Characteristics

Interim product/part characteristic absolute weights are calculated by multiplying scores for each relationship identified for particular interim product/part characteristics by the associated product/service characteristic relative weights, and summing these for each interim product/part characteristic.

Interim Product/Part Characteristic Target Values

These interim product/part characteristic target values represent what the project team feels are necessary to provide the important product service characteristics identified in the product planning matrix and, thus, satisfy the most important customer requirements.

Once the product design matrix is complete, the project team should know what interim product/part characteristics are most important to attaining the desired product/service characteristics. The project team should also have developed target values for key interim product/part characteristics to be used as a basis for product design. Now the project team can determine which interim product/part characteristics might present difficulties for the present production processes. This information is used to begin the process planning matrix.

For a product as complex as a complete ship, the identification of important interim product/part characteristics may be difficult using just the product design matrix described above. Alternatively, a matrix identifying system characteristics that address important product characteristics could be created, and then another matrix identifying interim product/part characteristics associated with these system characteristics could be created. This alternative process might allow the project team to more easily generate the information necessary to begin the process planning matrix.

The Process Planning Matrix

Pg. 3.

Overhead #32

The process planning matrix is used to translate important and potentially troublesome interim product/part characteristics into necessary process characteristics. An example of the process planning matrix is provided in Figure 11. Following are descriptions of each part of the process planning matrix.

Important Interim Product/Part Characteristics

The important interim product/part characteristics are transferred from the top axis of the product design matrix to the left axis of the process planning matrix. The target values and relative weights for each of these interim product/part characteristic are also transferred to the process planning matrix.

Process Steps and Characteristics

Process steps are identified for each important interim product/part and then the controllable process characteristics for each step are identified. These controllable process characteristics are essentially equivalent to process parameters or settings. A Failure Mode and Effects Analysis (FMEA), Figure 12, (**Overhead #33**) might be useful at this point to assure that all important process steps have been identified. A FMEA simply identifies the potential failure modes of all process steps, and then identifies the potential effects of each failure mode. Those process steps with higher potential for failure, or for which a loss of process control would likely result in unacceptable variance in interim product/part characteristics, should be included in the process planning matrix.

Relationship Matrix

The relationship matrix is used to identify relationships between the interim product/part characteristics and the process characteristics. The same symbols and values are used that were used in the product planning relationship matrix.

Absolute Weight, Process Characteristics

Process characteristic absolute weights are calculated by multiplying scores for each relationship identified for particular process characteristics by the associated interim product/part characteristic relative weights, and summing these for each process characteristic.

Relative Weight, Process Characteristics

Process characteristic relative weights are calculated by dividing each process characteristic absolute weight by the total of all process characteristic absolute weights and multiplying each of these numbers by 100.

Process Characteristic Target Values

These process characteristic target values represent what the project team feels are necessary to provide the important interim product/part characteristics identified in the product design matrix and, thus, satisfy the most important product/service characteristics and customer requirements. These target values can be used to determine whether current production processes have the required capabilities, or whether current processes need to be improved or replaced.

In a shipbuilding environment, the development of process planning matrices could become an overwhelming undertaking because of the huge number of interim products, parts, and process steps associated with a complete ship. If a shipyard has done a good job standardizing and classifying its interim products, it would probably be possible to complete a process planning matrix for each interim product type. Otherwise, the development of these matrices is reasonable

Part/Interim Product ID	Process Function	Potential Failure Mode	Potential Effects	Potential Causes	Frequency	Degree of Influence	Criticality	How Detected	Suggested Countermeasure	Results

Figure 12. Failure Mode Effects Analysis.

only if the project team has clearly identified the few specific interim products/parts that are vital, that will probably be difficult to produce, or for which the production process is unproved or not well understood, and those few process steps that would cause critical problems if they were to fail.

The Process Control Planning Matrix

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Overhead #34

The process control planning matrix is used to determine the degree of control required for each important production process identified in the process planning matrix. The objective of controlling each process is to prevent total process failure and to minimize process variation. Process control planning matrices are more flexible in format than the other matrices. Following is a description of each section of the process control planning matrix shown in Figure 13.

Interim Product/Part Identification

This column is for the important interim products or parts identified from the product design matrix.

Interim Product/Part Characteristic Target Values

These target values are taken directly from the product design matrix for the important interim products and parts identified.

Process Identification

This column is for the important processes identified in the process planning matrix, and associated with the interim product and part characteristic values that have been identified.

Process Characteristic Target Values

These targets are taken directly from the process planning matrix for the important processes that have been identified.

Remaining Columns

Additional columns are used to identify how the particular process characteristic target values will be maintained. Requirements identified might include training, maintenance, statistical process control, inspection, and resources (equipment and personnel).

When the process control planning chart is completed, the project team should have established all the process control procedures necessary to assure that key interim products and parts can be produced with the characteristics that will result in overall product/service characteristics that meet the customer requirements.

SECTION V. QFD CASE STUDIES

V. QFD CASE STUDIES

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QFD Prerequisites

Pg. 44

Users of QFD must understand that the QFD methodology is built upon a successive approximation of the voice of the customer. The QFD process facilitates the assimilation of this approximate perception of what the customer wants into a plan of action. This means that:

Every contribution is equally valuable and useful. No one person has enough perspective to be absolutely "right" with regard to identifying what the voice of the customer is saying. The objective is to gain as broad and accurate an approximation as possible of the voice of the customer through the open consideration of all available information and through the views of every project team member.

No input is to be criticized. Arguing is not appropriate. Positive discussion and critique of ideas is a necessity.

Diversity in project team membership is important. Membership should represent as many levels of project-related activity as practical (management, staff, engineering, planning, trades, etc.). This will increase the probability of obtaining useful results that can be successfully implemented.

Project team members should have a legitimate interest in the project, should have knowledge useful to the project, and should be knowledgeable of, and committed to, the QFD process.

Formal methods should be established to assure that all project team members have equal opportunity to contribute, i.e. select a leader, raise hands to speak, allow only one participant to speak at a time, self-police against inappropriate criticism.

The QFD methodology must be structured, disciplined, and systematic to assure that all possible representations of the voice of the customer are identified and considered, and also to provide traceability from the action plans derived during the QFD process back to the specific representations of the voice of the customer.

The project team should strive for consensus at each step in the QFD process. It is sometimes easy, during this process, which is by definition a process of successive approximation, to get bogged down in issues and details that have little overall significance. The objective of QFD is to identify and organize the key issues that the voice of the customer has identified, and to develop action plans that address these key issues.

It is not against the rules to go back in the QFD process and change things previously done if additional insight has been acquired by the project team. Just because the project team makes a decision at one point in the process does not mean that the decision has to be final.

Case Study #1: Offshore Supply Boat

Pg. 4

Create and analyze a House Of Quality/product planning matrix using the information and customer requirements provided below. Use brainstorming, affinity diagrams, and tree diagrams as necessary to identify and organize product characteristics related to the customer requirements. This case study does not require analysis and structuring of the voice of the customer; the customer requirements given can be assumed to be the result of such an analysis.

The Customer: Owner/operators of offshore supply vessels in the Gulf of Mexico.

Area of Desired Improvement/Breakthrough: These owner/operators want the next generation of offshore supply vessels to be better all-around than the vessels operating today.

Time Constraint: Because of the Persian Gulf war and the associated uncertainty about Middle Eastern oil supplies, oil production and exploration activity in the Gulf of Mexico showed some signs of recovery this past year. A few contracts have already been let for new offshore supply vessels. It is expected that demand for these vessels will increase as the present economic recession ends. A product development time frame of four months, from concept to completion of detailed production plans, is necessary for a builder/supplier to be in a competitive position once demand increases.

The Supplier: You are a small U.S. shipbuilder in the Gulf of Mexico region. You have experience building and repairing tugs, fishing trawlers, offshore supply vessels, dinner/excursion vessels, patrol craft, and other similar vessels in steel and aluminum up to 200 ft. in length. You have in-house design capability. Your total number of personnel has ranged from 10 to 175; current number of personnel is 87.

<u>Customer Requirements:</u>	<u>Customer Weight</u>	<u>Your Current Rating</u>	<u>Competitor Option "A"</u>	<u>Competitor Option "B"</u>
• Long range	4	3	4	3
• Can operate in bad weather	2	4	3	3
• Safe for the crew	5	4	3	4
• Easily maintained	4	3	2	5
• Versatile in cargo types/combinations	4	4	3	3
• Durable; will last long	3	3	3	4
• Economical to operate	5	3	2	4
• Comfortable for crew	2	3	4	2
• Fast	5	3	5	2
• Easy to operate	3	3	4	3
• Well built	4	3	3	4

Customer Weight: 1-not very important to the customer.
5-extremely important to the customer.

Current/Option Ratings: 1-not meeting customer requirement well.
5-meeting customer requirement extremely well.

Case Study #2: Submarine "Ocean Dog"

Pg. 4

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Navy personnel who have an interest in the next generation of attack submarine.

Area of Desired Improvement/Breakthrough: These Navy personnel want the next class of attack submarines, the "Ocean Dog," to be state-of-the-art with respect to the mission requirements of an attack sub.

Time Constraint: The Navy is expecting a contract design, preliminary production engineering, and a cost proposal for construction of the first ship of the class to be completed by both your shipyard and your competitor in three years.

The Supplier: You are the operations managers of a major U.S. shipbuilder with nuclear submarine design and construction experience.

Background: Your shipyard and another major shipyard with similar experience have each been awarded a contract for contract design and initial production engineering for the new class of attack submarine, and for a cost proposal for the construction of the first ship of the new class. At the end of this three-year contract, the Navy will choose one of the two shipyards to continue with detailed design, detailed production engineering, and construction of the first ship of the class.

Customer Statements:

- 1) Rear Admiral, "Ocean Dog" program head: "The 'Ocean Dog' must have the best integrated sonar and weapons-control systems that will be available when the ship is constructed. And the ship must be producible."
- 2) Rear Admiral, Chief Engineer of the Navy: "The 'Ocean Dog' must be able to go deeper than present attack subs, must be as quiet at flank speed as present subs are at low speed, and must be safe for the crew."
- 3) Captain, most experience active attack sub skipper in the Navy: "The next attack sub must be faster, more maneuverable, deeper diving, much quieter, easier to operate in all scenarios, and must be able to detect other vessels more effectively."
- 4) Captain, recently promoted to skipper of an attack sub, formerly a chief weapons officer: "The weapons system on the new sub must be more versatile, that is, capable of launching different types of weapons, and it must be reusable/loadable during a mission. Present vertical launch systems can launch only cruise missiles, and can be loaded only from external sources while on the surface using an independent crane. Present torpedo tubes can launch only torpedoes."
- 5) Lieutenant, engine room officer of an attack sub: "I hope the next generation of subs is more comfortable for the crew, and easier to maintain."
- 6) Master Chief, submarine reactor control electronics expert: "I wish the technical manuals were easier to use and understand."
- 7) Secretary of Defense: "The next generation of attack submarine, the 'Ocean Dog,' will be the most powerful weapon system of its kind in the world. It will be capable of seeking out and destroying enemy submarines and surface ships, and launching strikes against land-based targets without being detected. The 'Ocean Dog' will also be a good value for the taxpayer."

Case Study #3: Submarine Structural Interim Product

Pg. 4

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Shipyard personnel who work in the structural assembly trades and who will build the next generation of attack submarine.

Area of Desired Improvement/Breakthrough: These shipyard personnel want the next class of attack submarines, the "Ocean Dog," to be easier to build than present subs.

Time Constraint: The shipyard is expecting its contract design, preliminary production engineering, and cost proposal for construction of the first ship of the class to be complete in three years. The detail design and lead ship construction contract is expected shortly thereafter with fabrication for the lead ship starting within four years.

The Supplier: You are the operations managers of a major U.S. shipbuilder with nuclear submarine design and construction experience.

Background: Your shipyard and another major shipyard with similar experience have each been awarded a contract for contract design and initial production engineering for the new class of attack submarine, and for a cost proposal for the construction of the first ship of the new class. At the end of this three-year contract, the Navy will choose one of the two shipyards to continue with detailed design, detailed production engineering, and construction of the first ship of the class.

Your structural fitting and welding trades are responsible only for assembly work, and are not responsible for the fabrication of structural piece-parts, which might include initial blasting and coating of raw material, initial layoff, burning, shaping, edge prep, and affixing piece-part identifications.

Customer Statements:

- 1) Superintendent of structural fitters: "It would be nice if the fabrication trade could cut, roll, and edge prep shell plates and frames accurately enough so that we would not require excess material for fit-up. Can the designers help this situation for the next type of sub?"
- 2) Structural fitter foreman: "My job would be much easier if there were some uniformity to the structure of the hull sections in the parallel mid-body of the ship. Frame spacing, frame sizes, shell thickness, and circumferential shell seam spacing are not consistent in the present boats."
- 3) First class structural fitter: "I want the drawings, work instructions, and reference lines to be right."
- 4) Superintendent of structural welders: "Controlling weld distortion is our biggest problem on the present subs. Whatever design could do to help solve that problem would be great."
- 5) Structural welding engineer: "Simplifying the structural design would be a tremendous help from the standpoint of minimizing distortion and improving welder access and work position. We should also try to design for maximum use of automatic and semiautomatic welding processes."
- 6) Structural welding foreman: "Any pieces that have been fabricated incorrectly or poorly trimmed by the fitters will require weld build-up, increasing the chances for distortion, cracking, NDT failure, and rework. This can be a huge problem with major joints, such as when joining hull sections or installing a hard tank that must withstand depth pressure."
- 7) Structural welder: "Welding inside all of these tanks that are integral to the hull structure is very slow and tedious work, and is sometimes dangerous because of the cramped conditions and the preheat. Carbon arcing to repair cracks inside one of these tanks is just plain scary. It would be nice to have more room in these tanks to work, or to not have to go in the tanks to weld at all."

Case Study #4: Commercial Ship Design For Maintainability

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Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Owner/operator of a fleet of merchant ships of various types.

Area of Desired Improvement/Breakthrough: This owner/operator wants the new ships that he purchases to be designed to facilitate easier, faster, and less expensive maintenance, repair, and overhaul.

Time Constraint: This owner/operator will contract for the replacement for the oldest ship in his fleet, a bulk cargo ship, in six months. Your proposal is due to him in three months.

The Supplier: You are the operations managers of a major U.S. shipbuilder with past merchant ship new construction, repair, and overhaul experience. You would like to again build merchant ships. You have in-house design capability.

Background: An owner/operator of fifteen merchant ships has given you an RFP to bid on a replacement for his oldest ship. This owner/operator's fleet averages approximately seventeen years of age. He will be contracting for gradual replacement of the eleven oldest of his fifteen ships over the next eight years, starting in six months. You will, of course, be attempting to compete in the global shipbuilding market as you pursue this owner's business. Obviously, if you were to obtain his first contract, success on this ship would be very important to maintaining a relationship with this owner for future contracts, and for establishing your reputation as a competitive merchant shipbuilder. The owner/operator expects significant improvements or breakthroughs in a number of areas of design for his new ship, including maintenance and overhaul improvement.

Customer Statements:

- 1) "I want to minimize my operating expenses in the future partially by reducing the number of major overhauls required during the life of my ships and by minimizing the cost and duration of maintenance and overhaul work."
- 2) "The ship's crew must have very good access to all critical distributive systems and components while underway."
- 3) "Shipyard personnel must have good access to all distributive systems and components during overhaul and repair."
- 4) "The design must facilitate complete overhaul of all major components."
- 5) "Tank interiors, sea water systems, other systems carrying corrosive media, shafts, bilges, and hull exterior should have a minimum of corrosion at overhauls."
- 6) "All components chosen should have a documented high degree of reliability and should be widely available."
- 7) "The crew must be able to monitor and diagnose the condition of all major components on a real-time basis while underway."
- 8) "Required preventative maintenance should be minimized."

Case Study #5: Pipe Spools/Details

Pg. 5

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: Your shipyard personnel who work in the pipe fitting trades and who have experience building, repairing, and overhauling merchant ships.

Area of Desired Improvement/Breakthrough: These shipyard personnel want all pipe spools to fit properly during the outfit assembly processes.

Time Constraint: Your shipyard is pursuing a merchant ship contract. Executive management wants a recently identified, yet apparently chronic, pipe-fitting problem resolved quickly to justify the cost estimates that are being submitted as part of the proposal for merchant ship work. Executive management has given your project team two months to develop and implement an action plan. The shipyard's proposal for construction of the merchant ship is due in three months.

The Supplier: You are the operations managers of a major U.S. shipbuilder with past merchant ship new construction, repair, and overhaul experience. You would like to again build merchant ships. You have in-house design capability.

Background: An owner/operator of fifteen merchant ships has given your shipyard an RFP to bid on a replacement for his oldest ship. This owner/operator will be contracting for gradual replacement of the eleven oldest of his fifteen ships over the next eight years, starting in six months.

Although you would like to build merchant ships again, some of your current work practices, which have until now been considered "normal shipbuilding practice" (such as reworking pipe spools during assembly processes), are now considered unacceptable if you are to be competitive.

Customer Statements:

- 1) Pipefitter foreman: "Its fairly normal practice to work smaller diameter pipe spools around a bit on board to avoid interferences. The larger diameter spools that have interference problems get sent back to the fab shop for rework. Sometimes the fab shop sends them right back saying that they were fabricated to the correct dimensions. The spool might match the fab sketch but will not fit on the ship."
- 2) Pipefitter foreman: "There are periods of time when a good percentage of the pipe spools will come to a hull block or to the ship with flange rotations that either do not match the installation drawing or do not match the spools or components that they are supposed to fit."
- 3) First class pipefitter: "Half of the time the lines people have either put so many lines in a space that you don't know which ones to use, or they haven't put any lines in the space at all and we have to measure as best we can off of frames, bulkheads, and decks."
- 4) First year pipefitter apprentice: "Why are the installation drawings wrong all of the time?"
- 5) Master pipefitter: "We get some spools that have been dinged up or bent, and occasionally we get a spool that has the wrong ID number or that has been cut short. But there are enough of us down here who know enough to usually catch these mistakes. If the mistakes are minor we just fix them ourselves rather than hassle with sending them back to the fab shop."

Case Study #6: Water Tight Doors

Pg. 5

Create and analyze a House Of Quality/product planning matrix, a product design matrix, a process planning matrix, and a process control planning matrix using the information and customer statements provided below. Use brainstorming, the voice of the customer table (VOCT), affinity diagrams, and tree diagrams as necessary to expand on and organize the information provided.

The Customer: The customers are the fleet sailors represented by the NAVSEA Platform Directorate SEA 91.

Area of Desired Improvement/Breakthrough: A water-tight door that is easy to maintain and operate, and not too expensive to build.

Time Constraint: The Admiral in the SEA 91 position expects to leave his position within the next year and would like to have the new door designed and a prototype built before he leaves.

The Supplier: You are the team leader in the NAVSEA design code SEA 05xx responsible for water-tight doors.

Background: Present water-tight doors are of a design that existed before World War II. They are a proven door from the standpoint of damage control. However, they are heavy and must be dogged in several areas when secured. It takes a long time to dog a door, and frequently it is difficult to undog. There is a maintenance requirement to chalk test the door every 6 months to assure that the door is water tight. Frequently the doors fail the test and must be adjusted or the gasket must be replaced. On the other hand, NAVSEA has not heard a lot of complaints about the doors and SEA 91's complaint is one of many problems that face SEA 05.

Customer Statements:

- 1) SEA 91 to SEA 05: "When I was out at the Arizona Memorial it came to me that the ____ doors we use now are the same as we used then. They are no ____ good! When are we going to get a satisfactory door? My washing machine door isn't hard to operate and it doesn't leak, why don't we design a door like that?"
- 2) SEA 05 to SEA 91: "Doors haven't been high on our priority list, but we'll take a look at them and see what we can do."
- 3) SEA 05 to Design Leader: "SEA 91 says our doors are no ____ good. Frankly, I think he is right. My experience with them hasn't been good either but they are proven and we must not sacrifice the doors' effectiveness to satisfy other concerns. Go take a look at it, see what the complaints are, and what you can come up with."
- 4) Aircraft Carrier Master Chief: "The doors take an extensive amount of time to maintain. If I did what I'm required to do I'd have a team of people doing nothing but water-tight doors. I can't afford that."
- 5) D.C. First Class: "The chalk test requirement is not compatible with the door design. They hardly ever pass. We can't keep up with the requirement so we just groom the doors before our major inspections."
- 6) Ship's Captain: "The other day I couldn't get out of a compartment. Some strong-armed sailor dogged the door so tight I couldn't get it undogged."
- 7) Fleet Maintenance Officer: "Yeah, doors are one of our consistent maintenance items when we go alongside tenders."
- 8) Supply Officer: "I have a hard time keeping gasket material in stock. I'm not sure why we seem to use so much. I have heard complaints that it doesn't stand up to the service very well."
- 9) Shipyard Shipfitter Foreman: "We have to take the doors off in overhauls and frequently cut out the framing in order to widen the passage to get equipment out. The doors usually get straightened as part of the overhaul routine. However, when we weld the bulkhead back with the framing it's hard to hold the alignment so that the door will shut tightly. Consequently we have a lot of trouble with the compartment air tests. We have to adjust the hinges to get everything right."

Appendix "A"

References and Resources

- Prof. Yoji Akao, Tamagawa University, Quality Function Deployment, Integrating Customer Requirements Into Product Design, 1990, Productivity Press.
- Technicomp, Inc., 1111 Chestnut Avenue, 300 Park Plaza, Cleveland, Ohio 44114, 1-800-255-4440.
- GOAL/QPC and Bob King, 13 Branch Street, Methuen, MA 01844, 508-685-3900, Better Design In Half The Time, Implementing Quality Function Deployment In America, third edition, 1989, GOAL/QPC Press.
- American Supplier Institute, Inc., Six Parklane Blvd., Suite 411, Dearborn, MI 48126, 313-336-8877.
- Florida Power and Light-Quality Improvement Department, P.O. Box 14000, Juno Beach, FL 33408-0420, 305-552-4421.

Appendix "B"

Additional Notes On Using Quality Function Deployment

This section is a modified section of the book, Better Designs in Half the Time, by GOAL/QPC.

1.0 Using Quality Function Deployment

1.1 Introduction

Quality Function Deployment (QFD) is a multifunctional planning tool used by management to prioritize customer's demands and to develop reliable and cost effective responses.

QFD is a part of Total Quality Management (TQM). Total Quality Management is a way of doing business with a focus on customer satisfaction. An organization utilizing TQM is usually characterized by an environment of standardization, continuous improvement, and innovation as shown in Figure B-1. The TQM environment is summarized below in Table B-1.

Table B-1

Customer Driven Master Plan

Daily Control	Hoshin Planning	Cross Functional Management
<ul style="list-style-type: none"> • Statistical Methods • Work Groups • Standardization 	<ul style="list-style-type: none"> • Continuous Improvement • Vertical Teams • 7 "M" Tools 	<ul style="list-style-type: none"> • Information Systems • Audit Tools • Customer/Supplier • Q.A./Q.F.D.

The purpose of this appendix is to focus on QFD. Quality Function Deployment is a key component of cross-functional management, and is used for innovation.

1.2 QFD Options and QFD Strength & Weaknesses

There are two different approaches to QFD: a focused one credited to Don Clausing of Massachusetts Institute of Technology, and a generic one developed by Yoji Akao of Tamagawa University.

1.2.1 Focused Approach: Clausing

This approach is a modification of the QFD method used to assist in reliability engineering. Its value is its traceability from customer to manufacturing (see Figure B-2). It is very good for developing and improving parts and components, but is awkward for more complex products such as computers, automobiles, and ships. It is good for minor improvements in existing technology, but is not well suited for cost effective innovation. Clausing taught this approach to the American Supplier Institute.

The Total Quality Management/Control Environment

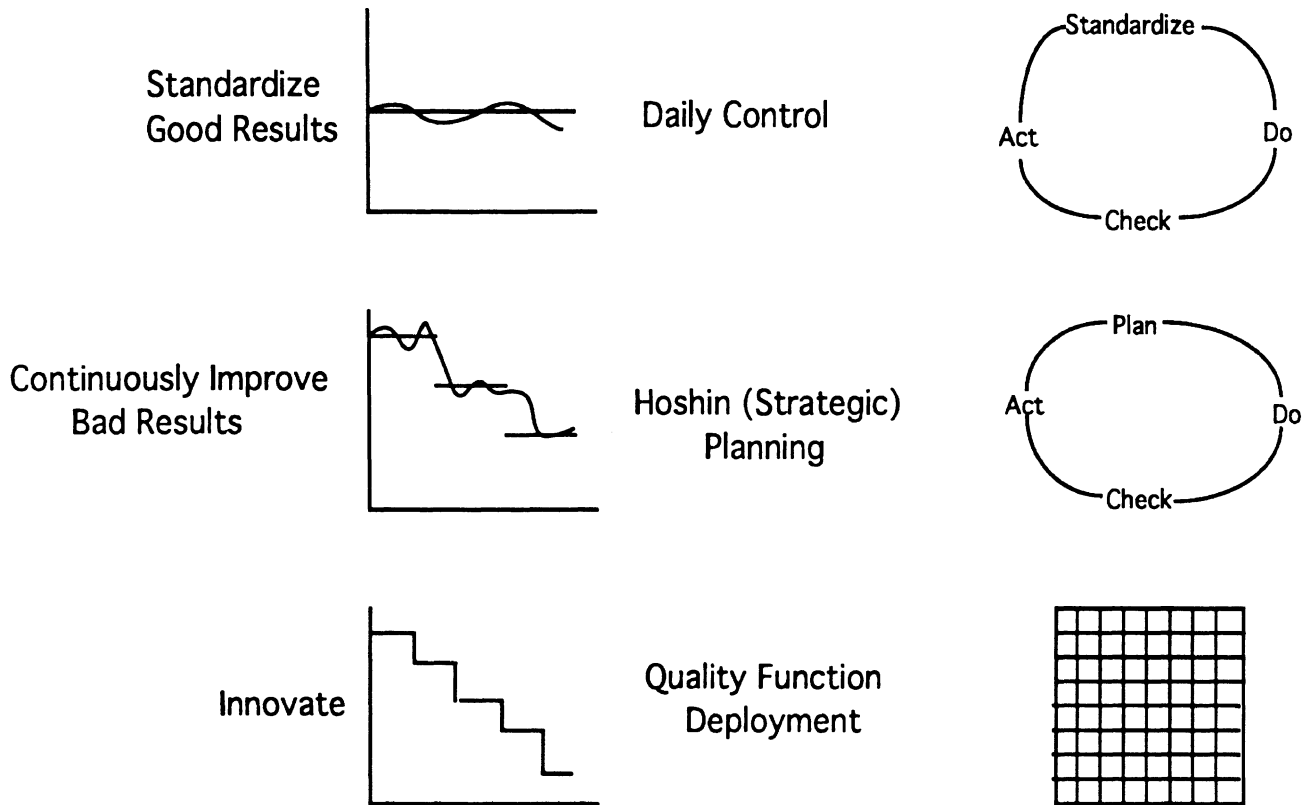


Figure B-1. Functions In A TQM Environment.

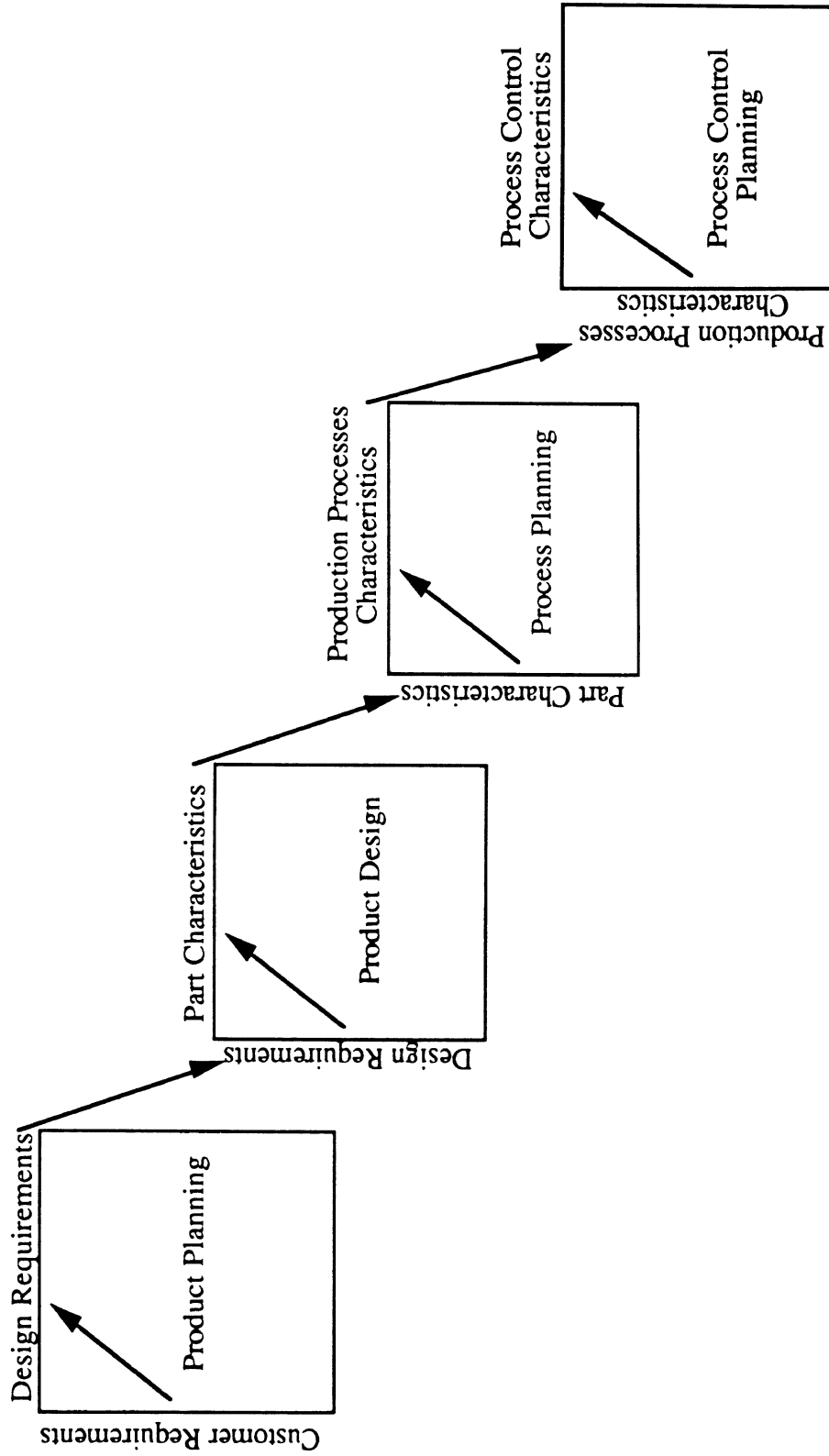


Figure B-2. Focused Approach.

1.2.2 Generic Approach: Akao

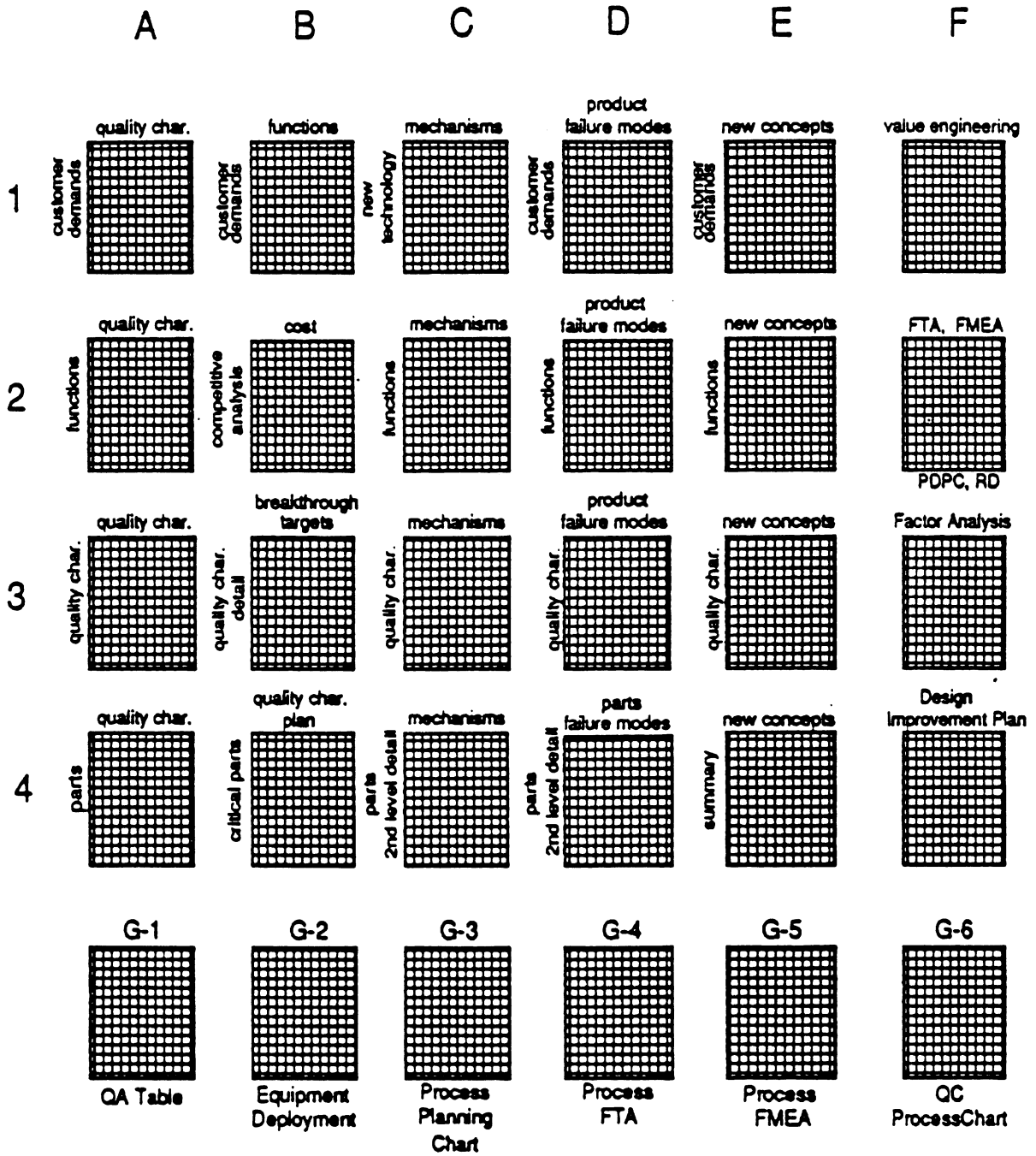
A more generic approach was developed by Yoji Akao in the mid-1980s. Its value was that it included linkages with value engineering and reliability charts such as Failure Mode & Effective Analyses (FMEA) and Fault Tree Analyses (FTA). An adaptation of his charts is presented in Figure B-3 as the "Matrix of Matrices." This adaptation has the benefit of providing a number of different formats for QFD matrices. Its major weakness, apart from its apparent complexity, is its lack of clear implementation steps. An effort has been made to solve this problem by setting up sequence steps for the matrices. Possible sequence steps are shown in Figure B-3.

Legend For Use With Figure B-3.

<u>Purpose to be Achieved</u>	<u>Charts to Use</u>
Analyze customer demands	A1, B1, D1, E1
Critique functions	A2, C2, D2, E2
Set quality characteristics	A1, A2, A3, A4, B3, B4, C3, D3, E3
Identify critical parts	A4, B4, C4, E4
Set breakthrough targets	B2, B3, B4, C1
Set cost targets	B1, C2, C3, C4
Set reliability targets	D1, D2, D3, D4
Select new concepts	E1, E2, E3, E4
Identify breakthrough methods	D4, F1, F2, F3
Identify manufacturing methods	G1, G2, G3, G4, G5, G6

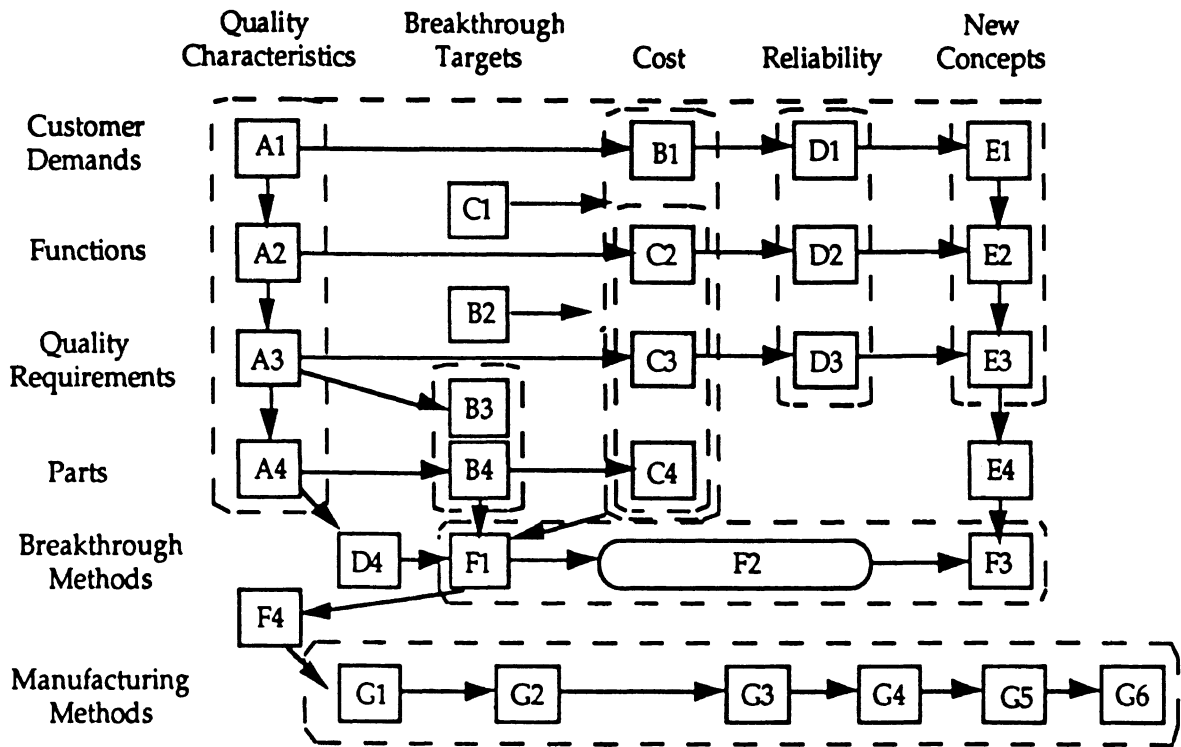
Figure B-4, along with the above legend, shows not only which charts should be completed first, but also identifies the general purpose of each chart. The disadvantage of this figure is that it suggests that the charts are static when, in fact, they are iterative.

Another way to sequence the chart is represented in Figure B-5. This chart has been well received in QFD classes.



Source: GOAL/QPC

Figure B-3. The Matrix of Matrices.



Purpose to be achieved

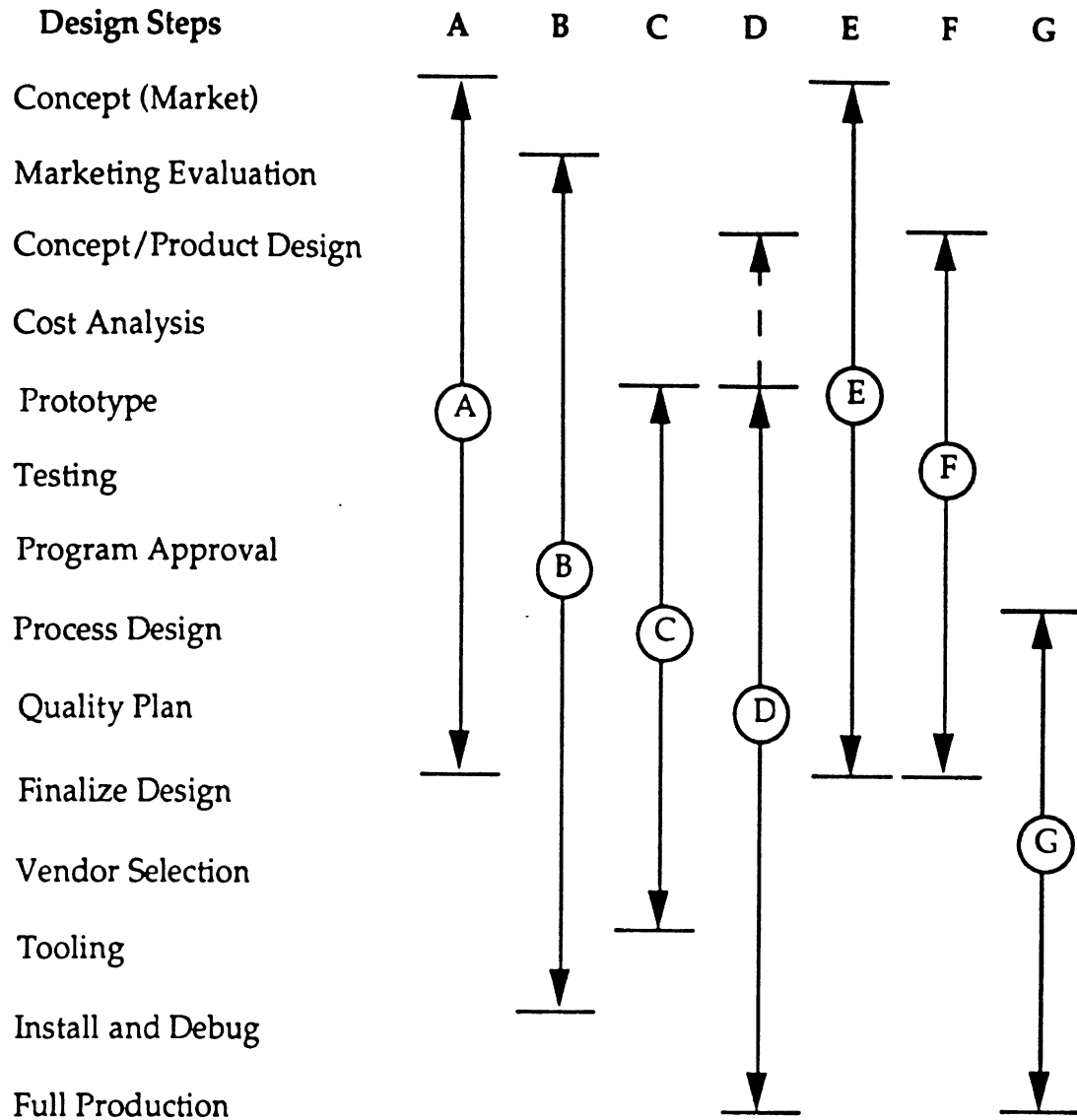
- Analyze customer demands
- Critique functions
- Set quality characteristics
- Identify critical parts
- Set breakthrough targets
- Set cost targets
- Set reliability targets
- Select new concepts
- Identify breakthrough methods
- Identify manufacturing methods

Charts to Use

- A1, B1, D1, E1
- A2, C2, D2, E2
- A1, A2, A3, A4, B3, B4, C3, D3, E3
- A4, B4, C4, E4
- C1, B2, B3, B4
- B1, C2, C3, C4
- D1, D2, D3, D4
- E1, E2, E3, E4
- D4, F1, F2, F3
- G1, G2, G3, G4, G5, G6

Source: GOAL/QPC

Figure B-4. Approaches To The Matrix of Matrices.



Source: GOAL/QPC

Figure B-5. Other Approaches to the Matrix of Matrices.

Appendix "C"

The Seven Management Tools

This section is a modified section of the book, Better Designs in Half the Time, by GOAL/QPC.

1.0 The Seven Management Tools

1.1 Introduction

There are seven management tools that can be used to facilitate project planning and decision making processes. Following are brief descriptions of each of these management tools.

For General Planning

- The Affinity Diagram: used to organize large amounts of data into groupings based on the natural relationship between data elements.
- The Interrelationship Diagram: used to identify and displays interrelated factors involved in complex problems. It also shows the relationships among factors.

For Intermediate Planning

- The Tree Diagram: used to systematically map out hierarchical relationships among data elements or groups of data elements, or to identify the full range of paths and tasks that need to be accomplished in order to achieve a primary goal.
- The Matrix Diagram: used to organize related groups of data such that the relationships, and the importance of the relationships, between individual data elements in each group are apparent.
- Matrix Data Analysis: used to arrange data shown in a Matrix Diagram, such that the relationships identified in the Matrix Diagram can be analyzed in more detail.

- The Process Decision Program Chart (PDPC): used to map out every conceivable event that may occur when moving from a problem statement to possible solutions.
- The Arrow Diagram: used to plan the most appropriate schedule for any task and to control it effectively as it progresses.

2.0 The Affinity/KJ Diagram

The affinity diagram gathers large amounts of data, such as ideas, opinions, and issues, and organizes them into groupings based on the natural relationship between each item. It is largely a creative, rather than a logical, process that occurs during discussion of a project.

The biggest obstacle to planning for improvement is past success or failure. It is assumed that what worked or failed in the past will continue to do so in the future. We therefore perpetuate patterns of thinking that may or may not be appropriate. Continuous improvement requires that new logical patterns be explored at all times.

The KJ Method is an excellent way to get a group of people to react from the creative gut level, rather than from the intellectual, logical level. It also efficiently organizes these creative, new thought patterns for further elaboration. Teams may produce and organize more than 100 ideas or issues in less than an hour. Think of how long that task would take using a traditional discussion process. It is not only efficient, it also encourages true participation because every person's ideas find their way into the process. This differs from discussions in which ideas are lost in the shuffle and are therefore never considered.

2.1 When to Use the Affinity Diagram

The affinity diagram is useful for organizing ideas around nearly any issue. However, there are applications that are more natural than others. The cleanest use of the diagram is in situations in which:

- facts or thoughts are in chaos. When issues seem too large or complex to grasp, use the diagram to map out the issue.
- breakthrough in traditional concepts is needed. When the only solutions are old solutions, use the diagram to expand the team's thinking.

- support for a solution is essential for successful implementation.

The affinity diagram is not suggested for use when the problem is simple, or requires a very quick solution.

2.2 Construction of the Affinity Diagram

The most effective group to assemble an affinity diagram is one that has the knowledge needed to uncover the various dimensions of the issue. The affinity process also seems to work most smoothly when the team is accustomed to working together. This enables team members to speak in a type of shorthand they know from their common experience. There should be a maximum of six to eight members on the team.

The following are the most commonly used construction steps.

1. Phrase the issue to be considered. It works best when it is stated vaguely. An example would be, "What are the issues surrounding Platen 5's support for the new welding process?" There should be no more explanation than that since more details may prejudice the responses toward the "old process."
2. The responses can be recorded in two different ways-
 - a. Record individual ideas on a flip chart pad and then transcribe them onto small cards, one idea per card.
 - b. Record individual ideas directly onto individual cards by a recorder or by the contributor themselves. It must be stressed that ideas should be concise and recorded exactly as stated. The aim should be to capture the essence of the thought.
3. The team should take the cards, mix them together, and spread them out randomly on a large table.
4. The cards can be grouped by the team or assigned to an individual in one of the following ways.

a. Look for two cards that seem to be related in some way. Place those to one side. Now look for other cards that can be related to the first two.

b. Repeat this process until you have all possible cards placed in no more than ten groupings. It may be necessary to duplicate specific ideas that seem to belong in more than one group. Do not force-fit single cards into groupings in which they don't belong. These single cards may form their own grouping or may never find another group.

Note: These are simply groups of ideas that hang together. They are not necessarily categories. It seems to be most effective to have everyone move the cards at will without talking. This prevents team members from getting trapped in semantic battles.

5. Transfer the information from cards onto paper with lines around each grouping. Related clusters should be placed near each other with connecting lines. From this the group can examine the data and make additions, deletions, and modifications.

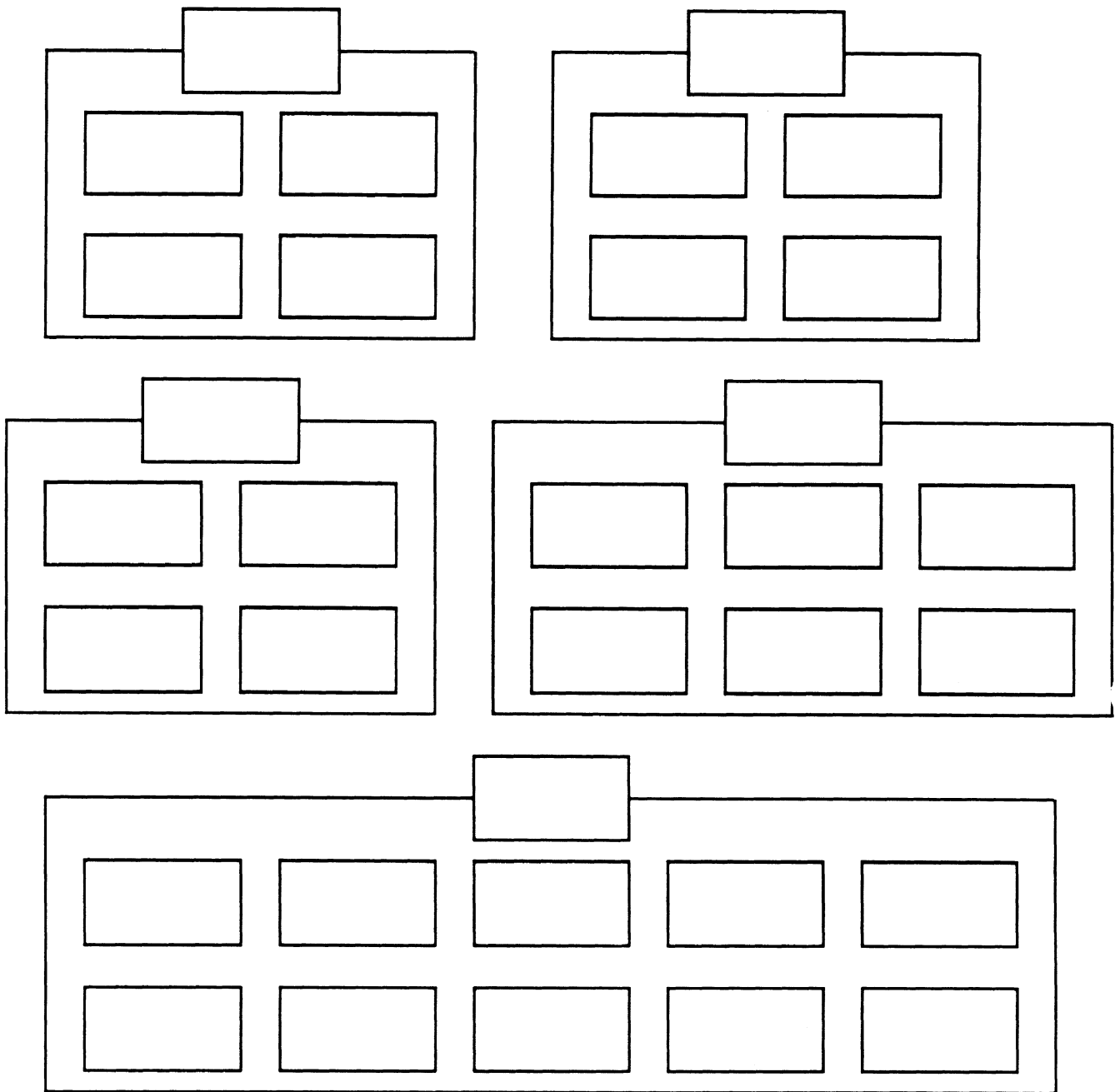


Figure C-1. Affinity Diagram.

3.0 Interrelationship Digraph

3.1 Definition

This tool takes a central idea, issue, or problem and maps out the logical or sequential links among related items. While still a very creative process, the Interrelationship Digraph begins to draw the logical connections that surface in the KJ Method.

In planning and problem solving, it is obviously not enough to just create an explosion of ideas. The KJ Method allows some initial organized creative patterns to emerge, but the Interrelationship Digraph (ID) lets logical patterns become apparent. This is based on the same principle that the Japanese frequently apply regarding the natural emergence of ideas. Therefore, an ID starts from a central concept, leads to the generation of large quantities of ideas, and finally to the delineation of observed patterns. To some this may appear to be like reading tea leaves, but it works incredibly well. Like the KJ, the ID allows those unanticipated ideas and connections to rise to the surface.

3.2 When to Use the Interrelationship Digraph

The ID is exceptionally adaptable to both specific operational issues and general organizational questions. For example, a classic use of the ID at Toyota focused on all of the factors involved in the establishment of a “billboard system” as part of the JIT program. On the other hand, it has also been used to deal with issues underlying the problem of getting top management support for TQC.

In summary, the ID should be used when:

- (a) an issue is sufficiently complex that the interrelationships among ideas are difficult to determine;
- (b) the correct sequencing of management actions is critical;
- (c) there is a feeling that the problem under discussion is only a symptom; and
- (d) there is ample time to complete the required reiterative process.

3.3 Construction of an Interrelationship Digraph

As in the KJ diagram and the remainder of the tools, the aim is to have the right people with the right tools working on the right problems. This means that the first step is to define the necessary blend of people for a group of six to eight individuals.

The construction steps are as follows:

1. Make one clear statement of the key issue under discussion.

Note: The source of this issue can vary. It may come from a problem that presents itself clearly. In this case, the ID would be the first step in the cycle rather than the KJ. The KJ is frequently used to generate the key issues to be explored in the ID.

2. Record the issue/problem statement. It can be recorded by
 - a. placing it on the same type of card as is used in the KJ, or
 - b. writing it on a flip chart.
3. To start the process, place the statement in one of two patterns.
 - a. a centralized pattern in which the statement is placed in the middle of the table or flip chart paper with related ideas clustered around it, or
 - b. a unidirectional pattern in which the statement is placed to the extreme right or left of the table or flip chart paper with related ideas posted on one side of it.
4. Generate the related issues/problems in one of the follow ways.
 - a. Take the cards from a grouping under KJ and lay them out with the one that is most closely related to the problem statement placed next to it. Then lay out the rest of the cards in sequential or causal order.

- b. Do wide-open brainstorming, place the ideas on cards and cluster them around the Central Statement, as in “a” above.
- c. Do wide-open brainstorming but directly onto the flip chart instead of cards. Proceed as in “a” and “b” above.

Note: The advantage of using cards is that they can be moved as the discussion progresses. The flip chart method is quicker, but can become very messy if changes occur.

Note: When using the flip chart method, designate all the related ideas by placing them in a single lined box.

5. Once all the related idea statements are placed relative to the central problem statement, fill in the causal arrows that indicate what leads to what. Look for possible relationships between each pair of ideas identified.

Note: At this step, you would look for patterns of arrows to determine what the key factors/causes are. For example, if one factor has seven arrows coming from it to other issues, while all others had three or fewer, then that would be a key factor. It would be designated by a double-hatched box.

6. Copy the ID legibly and circulate identified key factors to group members.
7. As in the KJ, you may draw lines around groupings of related issues.
8. Prepare to use the identified key factors as the basis for the next tool, the Tree Diagram.

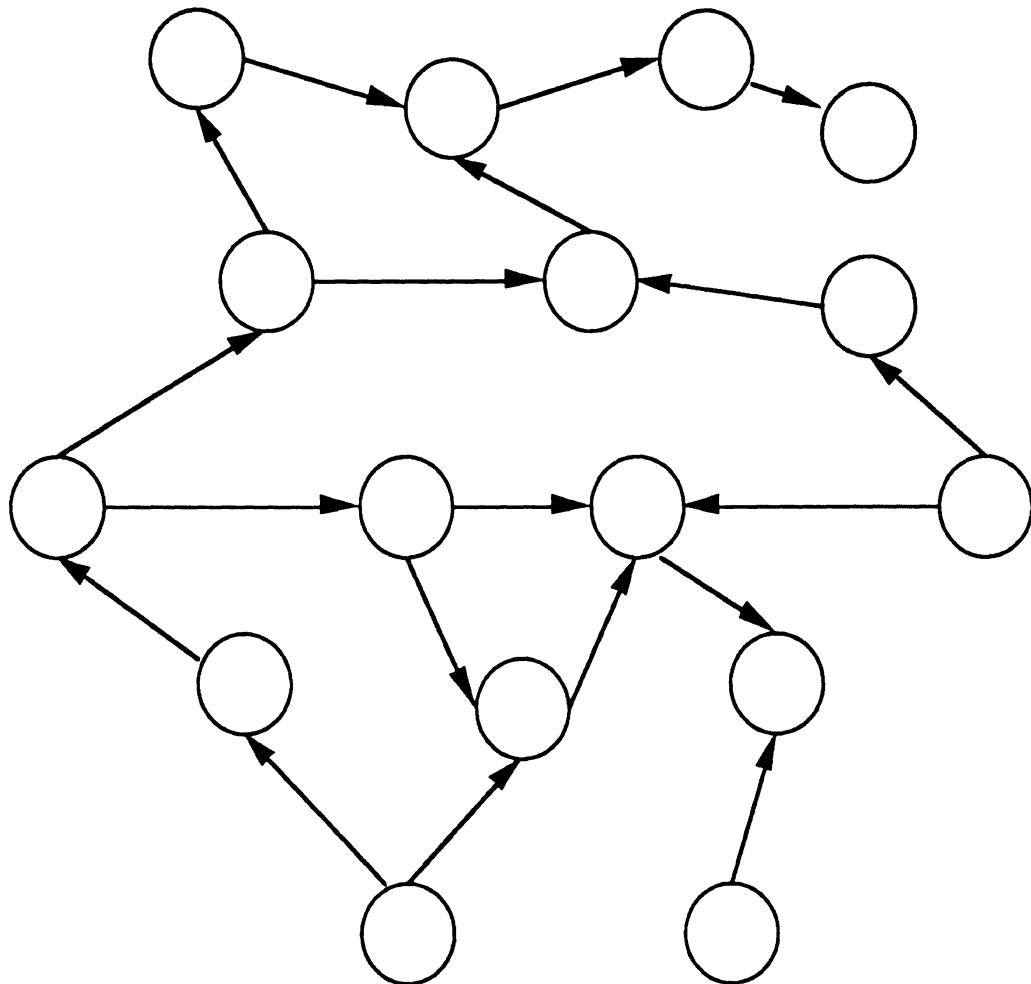


Figure C-2. Interrelationship Digraph.

4.0 SYSTEM FLOW/TREE DIAGRAM

4.1 Definition

This tool systematically maps out the full range of paths and tasks that needs to be accomplished in order to achieve a primary goal and every related subgoal. In the original Japanese context, it describes the “methods” by which every “purpose” is to be achieved.

In many ways, the KJ Method and Interrelationship Digraph force the key issues to the surface. The questions then become, “What is the sequence of tasks that need to be completed in order to best address that issue?” or “What are all of the factors that contribute to the existence of the key problem?” The Tree Diagram is appropriate for either question. Therefore, it can be used either as a cause-finding problem solver or as a task-generating planning tool. In either use, it brings the process from a broad level of concern to the lowest practical level of detail.

Another strong point is that it forces the user to examine the logical link between all of the interim tasks. This addresses the tendency of many managers to jump from the broad goal to details without examining what needs to happen in order for successful implementation to occur. It also rapidly uncovers gaps in logic or planning.

4.2 When to Use the Tree Diagram

The Tree Diagram is indispensable when you require a thorough understanding of what needs to be accomplished, how it is to be achieved, and the relationships between these goals and methodologies.

It has been found to be most helpful in situations such as the following:

- When you need to translate ill-defined needs into operational characteristics. For example, a Tree Diagram would be helpful in converting a desire to have an “easy to use VCR” into every product characteristic that would contribute to this goal. It would also identify the characteristics that can presently be controlled.
- When you need to explore all the possible causes of a problem. In this application the Tree Diagram is called a Cause & Effect Diagram or Fishbone Chart. Such a chart could be used to uncover all of the reasons why top management may not support a continuous improvement effort.

- When you need to identify the first task that must be accomplished in reaching a broad, organizational goal. For example, the Tree Diagram could be very helpful in the coordination of Quality Improvement Programs by identifying what is already being accomplished and where the key gaps exist.
- When the issue under question has sufficient complexity and time available for solution. For example, a Tree Diagram would not be particularly helpful for deciding how to deal with a product contamination problem that is shutting down you production line. It could be used to prevent it from recurring, but not in deciding on the stop-gap measures to be taken.

Note: In its most common usage the Tree Diagram conceptually resembles the Cause & Effect Diagrams. It is easier to interpret because of its clear, linear layout, and it also seems to create fewer loose ends than the C&E.

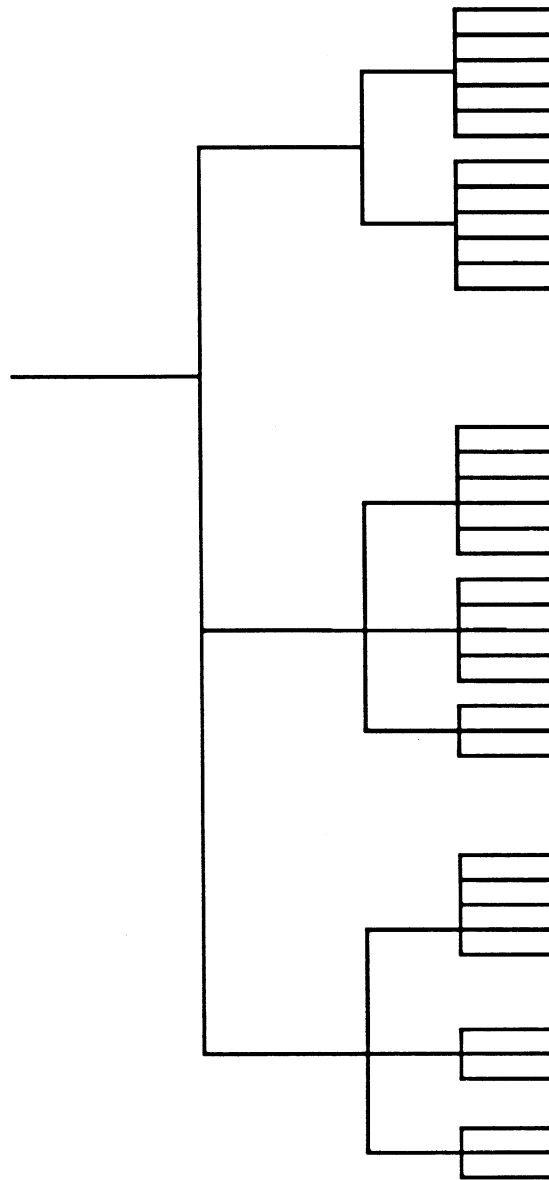


Figure C-3. Tree Diagram.

4.3 Construction of a System Flow/Tree Diagram

It has been shown that these tools are most powerful when used in combination, but they are also very effective when applied singly. With this in mind, the following are the most widely used steps:

1. Agree upon one statement that clearly and simply states the core issue, problem, or goal. This statement may or may not come from a KJ Chart or Interrelationship Diagram.

Note: Unlike the KJ Method, the Tree Diagram becomes more effective as the issue is more clearly specified. This is important since the emphasis is on finding the logical and sequential links between ideas/tasks and not on pure creativity.

2. Once the statement is agreed upon, the team must generate all of the possible tasks, methods, or causes related to that statement. These could follow three different formats.
 - a. Use the cards from the KJ Chart as a foundation. For example, you might take the 10-20 cards that fall under one broad heading as a starting point.
 - b. Brainstorm all of the possible related tasks/methods/causes and record them on a flip chart. These ideas could then be placed on individual cards or rearranged on the flip chart.
 - c. Brainstorm and record directly onto cards for continued use.

Note: When brainstorming, continue to apply to each idea the question "In order to achieve X, what must happen or exist?" Or "What has happened or what exists that causes X?"

3. Evaluate and code all of the ideas with the following:
 - O Possible to carry out
 - L Need more information to see if possible
 - X Impossible to carry out

Note: Code an idea to be impossible only after very careful consideration. "Impossible" must not be equated with "we've never done it before."

4. Construct the Actual Tree Diagram.

- a. Place the central goal/issue card to the left of a flip chart or table. (The remainder of the instructions will assume that cards are being used, but the same steps would apply if the chart is drawn directly on the flip chart.)
- b. Ask the question, "What method or task do we need to complete in order to accomplish this goal or purpose?" Find the ideas on the cards or flip chart list that are most closely related to that statement. These may also be viewed as those tasks that are the closest in terms of sequence or cause and effect.
- c. Place the ideas/tasks from "b" immediately to the right of the central issue card as you would in a family tree or organizational chart.
- d. The ideas/tasks from "c" now become the focal point. In other words, the question from "b" is repeated and the remaining cards are again sorted to be placed to the right as the next row in the tree. This process is repeated until all of the cards or recorded ideas are exhausted.

Note: If none of the cards answer the repeated question, create a new card and place it in the proper spot.

- e. Review the entire Tree Diagram to ensure that there are no obvious gaps in sequence or logic. Check this by reviewing each path, starting at the most basic task to the extreme right. Ask of each idea/task, "If we do Y, will it help lead to the accomplishment of this next idea/ task?"
- f. Review with other groups for relevant input and revise where needed.

5.0 Matrix Diagram

5.1 Definition

This tool organizes large groups of characteristics, functions, and tasks in such a way that logical connecting points among each are graphically displayed. It also shows the importance of each connecting point relative to every other correlation.

Of the tools discussed thus far (KJ Method, Interrelationship Digraph, System Flow/Tree Diagram), the Matrix Diagram has enjoyed the widest use. It is based on the principle that whenever a number of items are placed in a line (horizontal) and other items are placed in a row (vertical), there will be intersecting points that indicate a relationship. Furthermore, the Matrix Diagram features highly visible symbols that indicate the strength of the relationship among the items that intersect at that point. The Matrix Diagram is very similar to the other tools, in that new, cumulative patterns of relationships emerge based on the interaction between individual items. Even in this most logical process, unforeseen patterns just happen.

5.2 When to Use the Matrix Diagram

Because the Matrix Diagram has enjoyed the widest use of the new tools, it has evolved into a number of forms. The key to applying a Matrix Diagram successfully is choosing the right format matrix for the situation. The following are the most commonly used matrix forms.

5.3 Matrix Diagram Shapes

The most basic form of Matrix Diagram is the L-shaped diagram. In the L shape, two interrelated groups of items are presented in line and row format. It is a simple, two-dimensional representation that shows the intersection of related pairs of items as shown in Figure C-4. The Matrix Diagram may be used to display relationships among items in countless operational areas such as administration, manufacturing, personnel, and R&D. There are also matrices in the shape of Ts, Ys, Xs, and Cs for comparing various types and numbers of information sets.

			A				B			
			1	2	3	4	5	6	7	8
1	1.1	1.11								
		1.12								
	1.2	1.21								
		1.22								
2	2.1	2.11								
		2.12								
		2.13								
	2.2	2.21								
		2.22								

Figure C-4. Matrix Diagram.

5.4 Matrix/Tree Diagram Relationships

Generating the most complete set of items possible is as important as selecting the right matrix shape. The Tree Diagram is widely used to generate the tasks, ideas and/or characteristics that form one or more sides of a matrix.

Figure C-4 also shows how two tree diagrams have been merged into a simple L-shaped matrix. The tree diagrams might represent a set of tasks to be accomplished (vertical axis of matrix) and the departments/functions of an organization (horizontal axis). The degrees of responsibility of each task can then be clearly allocated and indicated.

5.5 Construction of a Matrix Diagram

The process of constructing any of the various forms of Matrix Diagrams is very straightforward.

1. Generate the two, three, or four sets of items that will be compared in the appropriate matrix.

Note: These often emerge from the last row of detail in a Tree Diagram. This is the most effective method, but the matrix has proven helpful when based upon brainstormed items from a knowledgeable team.

2. Determine the proper matrix format. The choice of sets of items to compare is based on an educated guess, experience, and trial and error. Don't be afraid to abandon or modify a line of reasoning.
3. Place the sets of items in such a way as to form the axes of the matrix. If these items come from one or more Tree Diagrams, you can simply tape the cards (if used) on a flip chart pad. Otherwise, you can simply record the items directly on the pad. Finally, draw the lines that will form the boxes within which relationship symbols will be placed.

4. Decide on the relationship symbols to be used. The following are the most common, but use your imagination.

- Function Responsibility Chart

P - Primary Responsibility

S - Secondary Responsibility

T - Tertiary Responsibility (should receive more information)

- Quality Characteristics Chart

A - Most Critical

B - More Critical

C - Critical

- Product Testing Chart

- - Test in Process

O - Test Scheduled

X - Test & Evaluation Possible

Note: Regardless of which symbols you choose, be sure to include a legend that prominently displays the relationship symbols and their meanings.

6.0 Matrix Data Analysis

6.1 Definition

Matrix Data Analysis is accomplished by arranging data displayed in a Matrix Diagram so that it can be more easily viewed to reveal the true strength of the relationships among variables.

6.2 When to Use Matrix Data Analysis

Matrix Data Analysis is primarily used for market research, planning, development of new products, and process analysis. It is used to determine the representative characteristics of each variable being examined. For example, what are the demographic characteristics of groups of people who like or dislike certain foods? What are the representative characteristics of a new cloth given an array of possible end uses.

6.3 Construction of a Matrix Data Analysis Diagram

1. In order to find the "representative characteristics" of a product or consumer, use the "Principal Component Analysis Method." This is a formula that mathematically calculates the impact of a factor on a process.
2. Compare data among evaluation groups showing how much of the intergroup variation is due to a particular characteristic of that group.
3. Calculate the cumulative contribution rates of the principle components to the overall ratings.
4. Display the distribution of results graphically in a four-quadrant chart.

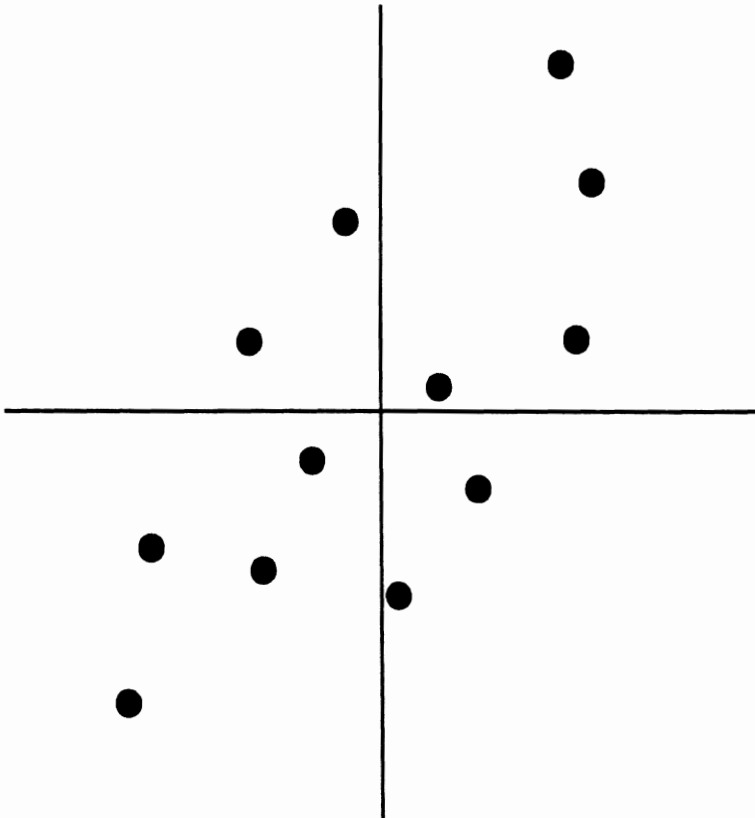


Figure C-5. Matrix Data Analysis.

7.0 Process Decision Program Chart (PDPC)

7.1 Definition

Process Decision Program Chart (PDPC) is a method that maps out every conceivable event and contingency that can occur when moving from a problem statement to possible solutions. This tool is used to plan each possible chain of events that needs to occur when the problem or goal is an unfamiliar one. The underlying principle behind the PDPC is that the path toward virtually any goal is filled with uncertainty.

PDPC anticipates the unexpected and, in a sense, attempts to short circuit the cycle so that the check takes place during a dry run of the process. The beauty of PDPC is that it not only tries to anticipate deviations, but it also facilitates development of countermeasures that will either

- a. prevent the deviation from occurring, or
- b. be in place in case the deviation occurs.

The first option is ideal in that it is truly preventive. However, we live in a world of limited resources. In allocating these resources we have to often play the odds as to the chance of X, Y, or Z happening. Given that fact, the next best thing is to have a contingency plan in place for a situation that occurs when we are betting against the odds. PDPC provides a structure to support both prevention and reaction.

7.2 When to Use a Process Decision Program Chart

PDPC is like the Tree Diagram in structure and aim, since both deal with possible patterns of methods and plans. In the same vein, it is closely tied to methods in reliability engineering such as Failure Mode & Effective Analysis (FMEA) and Fault Tree Analysis (FTA).

The prime difference between these two types of Process Decision Program Charts is that FMEA starts from the smallest detail (subsystem) and assesses the probability of failure at any step. Also, it determines the cumulative impact on the end goal. FTA, on the other hand, starts with an undesirable result and then traces it back, sequentially looking for the cause. PDPC is enjoying widespread use in particular because of the stress on product liability.

7.3 Construction of a Process Decision Program Chart

Even though the construction of a PDPC is a methodical process, it has few guidelines in terms of the process and finished product. The most important thing to keep in mind is that you must get to the point where deviations and contingencies are clearly indicated. This must be true at every level of detail in the chart.

Note:

The goal statement that starts the PDPC process often emerges from tools such as the KJ, Interrelationship Digraph, or even the Tree Diagram. As is true of all the other tools, PDPC can also be used effectively on its own.

One word of caution: The creation of possible paths and countermeasures can multiply the complexity of the chart tremendously. Don't let it overwhelm you. Break the material into bite-sized pieces, develop each piece, and then reassemble the final product.

The following seems to be the most workable approach:

- a. Follow the instructions for the Tree Diagram through to the end.
- b. Take one branch of the Tree Diagram (starting from the purpose in the row to the immediate right of the ultimate goal/purpose) and ask the questions: What could go wrong at this step? or What other path could this step take?

Note: It is easier if the items in that original branch are on cards so that they can be moved easily. This is important because you are inserting problems and countermeasures into an existing sequence.

- c. Answer the questions in "b" by branching off the original path.
- d. Off to the side of that step, list actions or countermeasures that could be taken. These are normally enclosed in "clouds" similar to cartoon captions and attached to that problem statement.
- e. Continue the process until that original branch is exhausted.
- f. Repeat "b" through "e" on the next most important tree branch, etc.

- g. Assemble the individual branches into a final PDPC, review with the proper team of people, and adjust as needed.

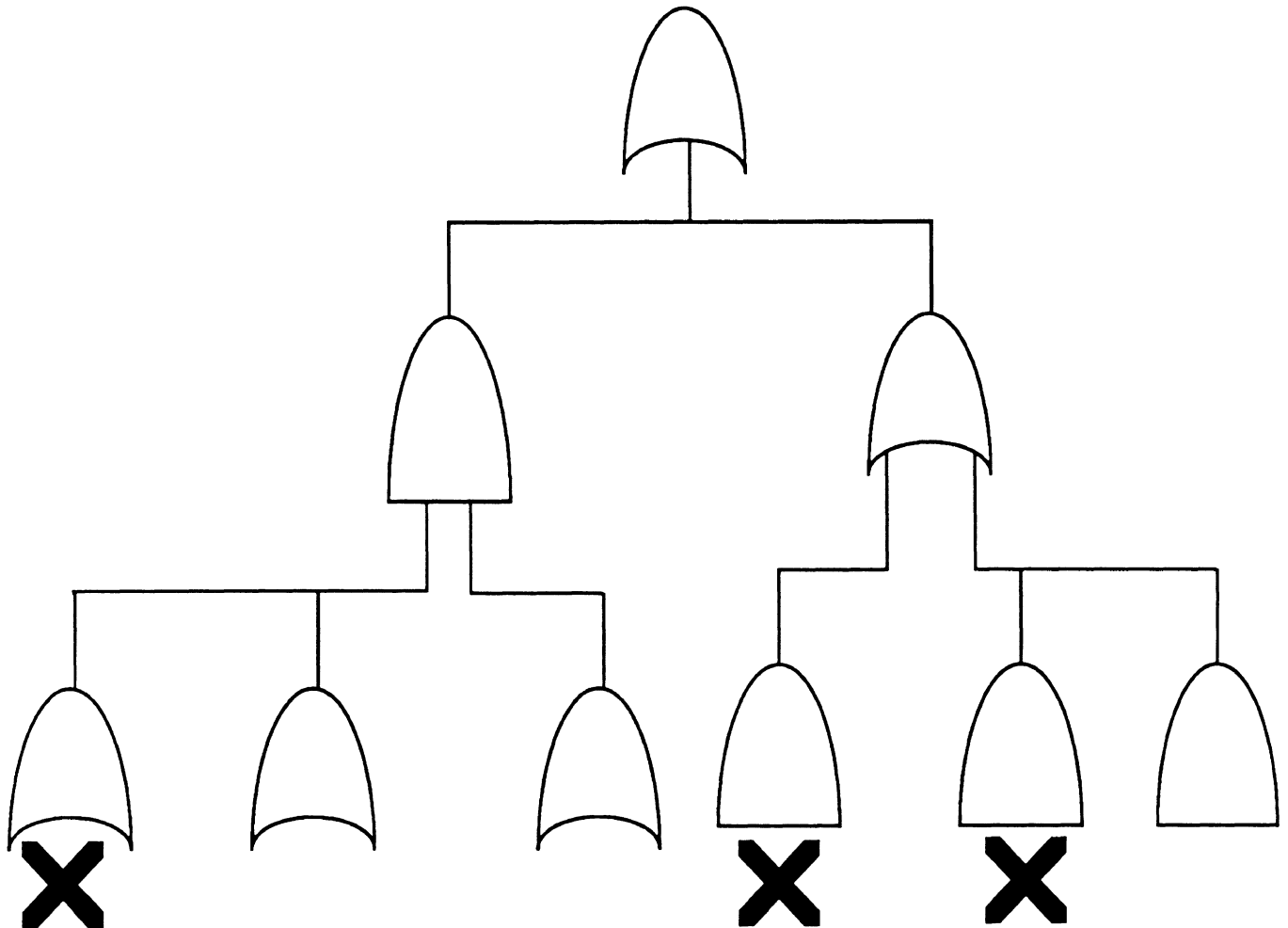


Figure C-6. Process Decision Program Chart.

8.0 Arrow Diagram

8.1 Definition

This tool is used to plan the most appropriate schedule for any task and to control tasks effectively as they progress. This tool is closely related to the CPM and PERT Diagram methods. It is used when the task at hand is a familiar one with subtasks that are of a known duration.

The arrow diagram is based on the Program Evaluation and Review Technique (PERT), which was developed in the United States during the 1950s to aid the development of the U.S. Navy's Polaris Missile program. The Arrow Diagram removes some of the magic from the traditional PERT process. This is consistent with the general idea that the key to Japanese success is their ability to take previously available tools and make them accessible to the larger population. So, instead of industrial, manufacturing, and design engineers papering their walls with PERT charts, they can be used as a daily tool throughout the organization.

8.2 When to Use the Arrow Diagram

The most important criterion is that the subtasks, their sequencing, and their duration must be well known. If this is not the case, then the construction of the Arrow Diagram can become a very frustrating experience. When the timing of the actual events is very different from the Arrow Diagram, people dismiss the Arrow Diagram as a nuisance, never to be used again. When there is a lack of process history, the PDPC is usually a much more helpful tool.

Note:

Do not be afraid to admit that you may not know everything there is to know about a process. It is better to decide on the proper tasks and sequencing than to pretend that you have a handle on the scheduling dimension.

Obviously, there are many processes that do have a well documented history. Therefore, the Arrow Diagram has enjoyed widespread use in such areas as:

- New Product Development
- Construction Project Control
- Marketing Planning
- Complex Negotiations

8.3 Construction of an Arrow Diagram

As usual, a successful process is based on having complete input from the right sources. It is possible that one person could have all of the needed information for structuring an Arrow Diagram, but it is highly unlikely. Therefore, assembling a team of the right people is the first step. This team would follow the steps listed below.

1. Generate and record all the necessary tasks to complete the project.
2. Determine the interrelationships between the tasks (what precedes, follows, or is simultaneous to each task), placing them in the proper flow. Delete duplications and add new tasks if jobs are overlooked.
3. Once these paths between tasks are established, write in the nodes, number them, and add arrows between tasks in each path and between paths as necessary. Each task is made up of two nodes. The task that begins with node #1 and ends with node #2 is task 1,2.
4. Carefully study the number of days, hours, weeks, etc. and calculate the earliest and latest start time for each node.

The use of an Arrow Diagram is necessary to calculate the Critical Path (from Critical Path Method), which is the longest cumulative time that the tasks require. This is, therefore, the shortest time in which one could expect the final tasks to be completed.

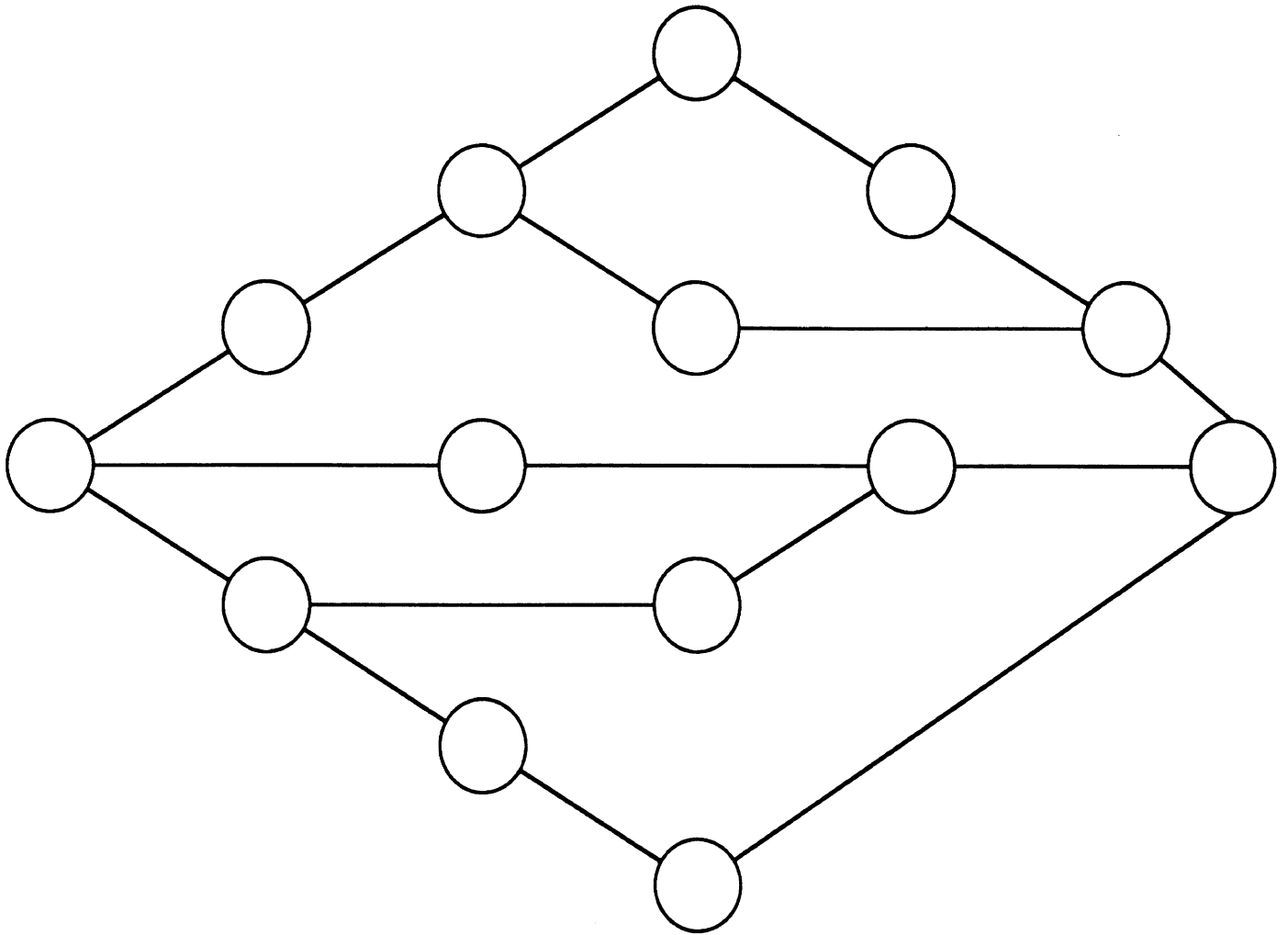


Figure C-7. Arrow Diagram.

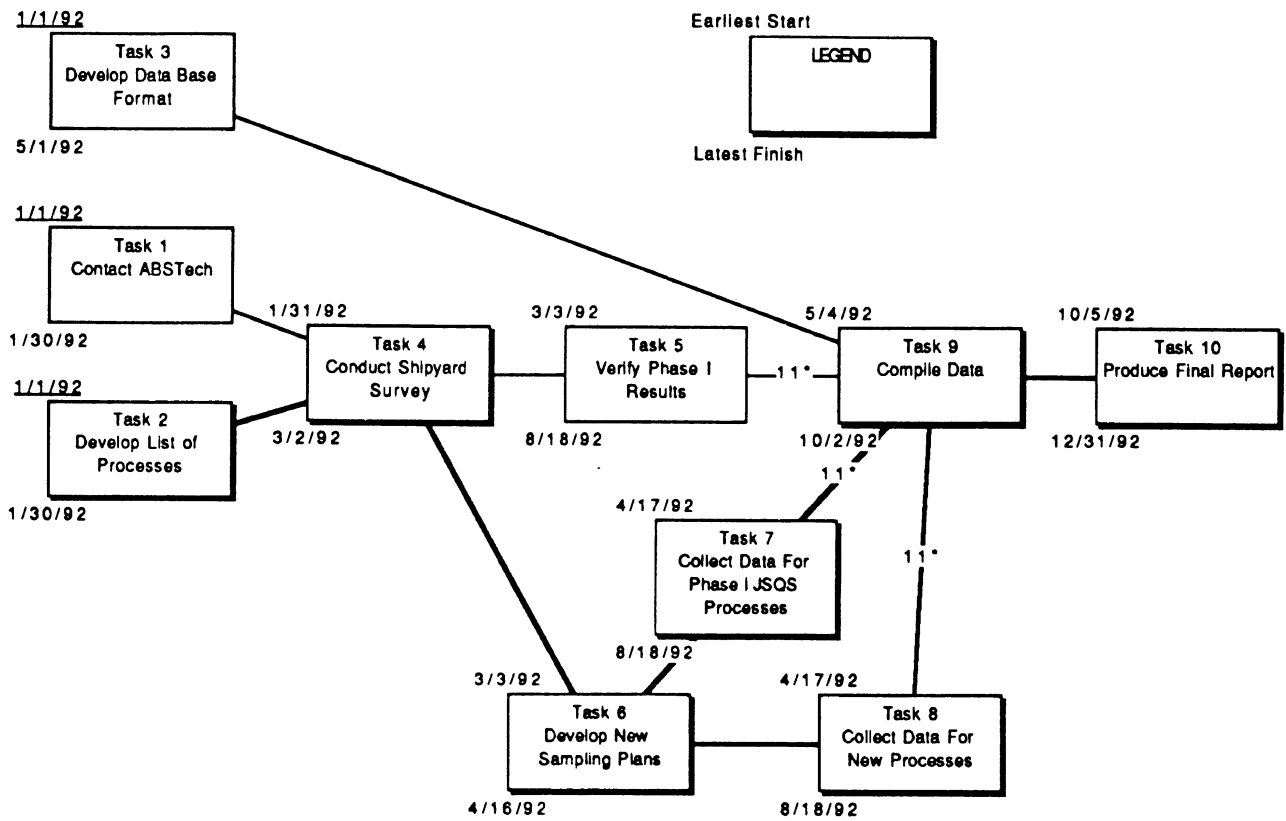


Figure C-8. CPM Network Diagram.

Appendix "D"

Basic QFD Example:

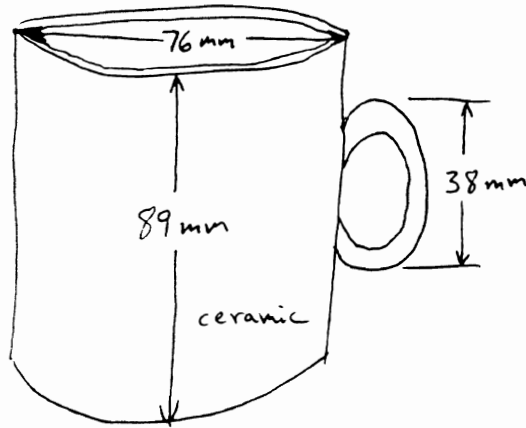
"Captain's Coffee Cup"

QFD Example: "Captain's Coffee Cup"

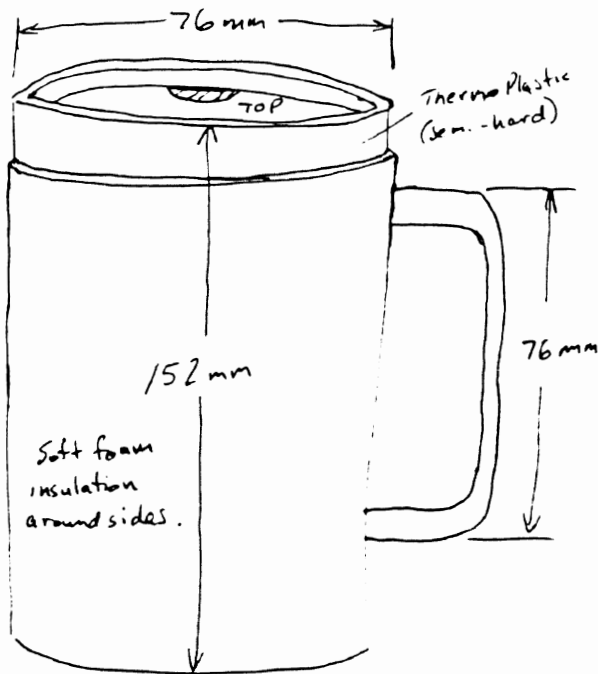
Customer: People who use cups for drinking on boats.

Project Focus Area: Create best cup for use on a boat.

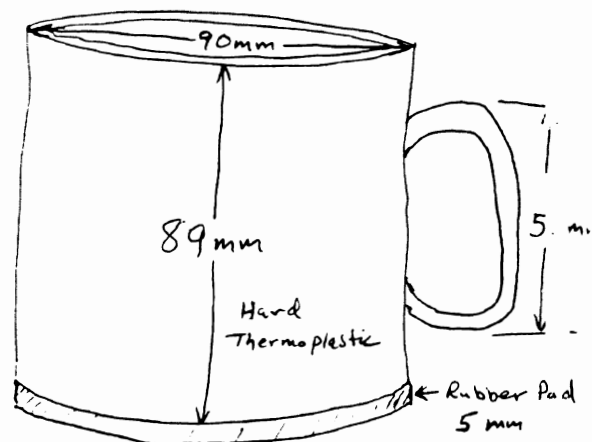
Time Constraint: 6 months from start of product development to market.



Current Cup



Competitor "A"



Competitor "B"

Product/Service Characteristics	Customer Requirements											Performance Metrics										
	Height	Bottom Area	Handle Size	Top Area	Durability of Mat'l	Color	Volume	Height of CG, %	Bottom Coef. of Fric.	Insulation Value	Top Covered?	Weight	Customer's Weight	Current Rating	Option "A" Rating	Option "B" Rating	Target Rating	Improvement Ratio	Key/Sales Point	Absolute Weight	Relative Weight, %	Ranking
Holds A lot	○	○		○			⊙						4	3	5	4	4	1.3	1.2	6.2	8.3	6
Keeps Drink Warm	△			○					⊙	○			5	4	5	3	5	1.2	1	6.0	8.1	7
Stable	○	⊙	△	△			⊙	△			△		5	3	2	5	5	1.7	1.5	12.7	17.0	2
Stays Where Put		○					○	⊙			⊙		4	2	1	5	5	2.5	1.2	12.0	16.1	3
Durable			△		⊙						△		5	3	4	3	5	1.7	1	8.5	11.4	5
Looks Good	△	△	○	△		⊙	△				△		2	2	1	3	3	1.5	1.5	4.5	6.0	8
Splashless	△			⊙						⊙			4	2	5	3	4	2.0	1.2	9.6	12.9	4
Easy To Hold	△		⊙				○	○	△	○	○		4	2	5	2	5	2.5	1.5	15.0	20.1	1
													Absolute Weight: 123, 232, 227, 189, 103, 64, 81, 262, 162, 133, 167, 234 → 1966 Relative Weight, %: 6.3, 11.8, 11.5, 9.6, 5.2, 2.7, 4.1, 13.3, 8.2, 6.8, 8.5, 11.9 Ranking: 9, 3, 4, 5, 10, 12, 11, 1, 7, 8, 6, 2 Unit of Measure: mm, mm ² , mm, mm ² , see below, n/a, R, mm, %, n/a, R, mm, mm ² Current Value: 89, 450, 38, 450, 3.5, width, .34, 40, 0.1, 2, no, 369 Option "A" Value: 152, 450, 76, 450, 00, room, .60, 42, 0.15, 6, yes, 200 Option "B" Value: 94, 620, 51, 200, 4.1, mm, .51, 39, 0.30, 3, no, 400 Target Value: 127, 800, 100, 300, >10, mm, .55, 30, 0.4, 5, yes, 375									
Special Req's:	ABS																					
	Cst. Grd.																					
	Standard																					

- Strong Positive
- Some Positive
- × Some Negative
- * Strong Negative

- 9, Strong Relationship
- 3, Moderate Relationship
- △ 1, Weak Relationship

* Height from which a 10mm steel ball is dropped causing permanent damage to the cup. (in meters)

Product Planning Matrix.

Interim Product/ Part Characteristics			Captain's Coffee Cup											
			Cup Body			Cup Handle			Cup Bottom		Cup Top			
Important Product/Service Characteristics	Target Value	Relative Weight	Mat'l. Type	Bottom Thickness	Height	Bottom Diameter	Opening Height	Opening Width	Thickness	Mat'l. Type	Thickness	Bottom Surface Finish	Mat'l. Type	Thickness
			Height of CG, %	30	13.3	⊙	⊙						○	△
Bottom Area, mm ²	800	11.8			⊙									
Handle Size, mm	100	11.5		○		⊙	⊙	○						
Top Area, mm ²	3100	9.6		△	○									
Top Covered, yes/no	yes	8.5											⊙	⊙
Bottom Coef. of Fr. c	.4	8.2							⊙		⊙			
Weight	375	11.9	⊙				○	○	○	○	○		○	○
Insulation Value R	5	6.8	⊙						○	○			○	○
Absolute Weight			168	120	164	155	139	10	170	69	74	13	146	
Relative Weight			10.7	7.7	10.5	8.6	8.4	8.2	4.2	10.8	4.4	4.7	11.0	4.3
Target Value			6	24	100	45	25	3	3	1	3		3	

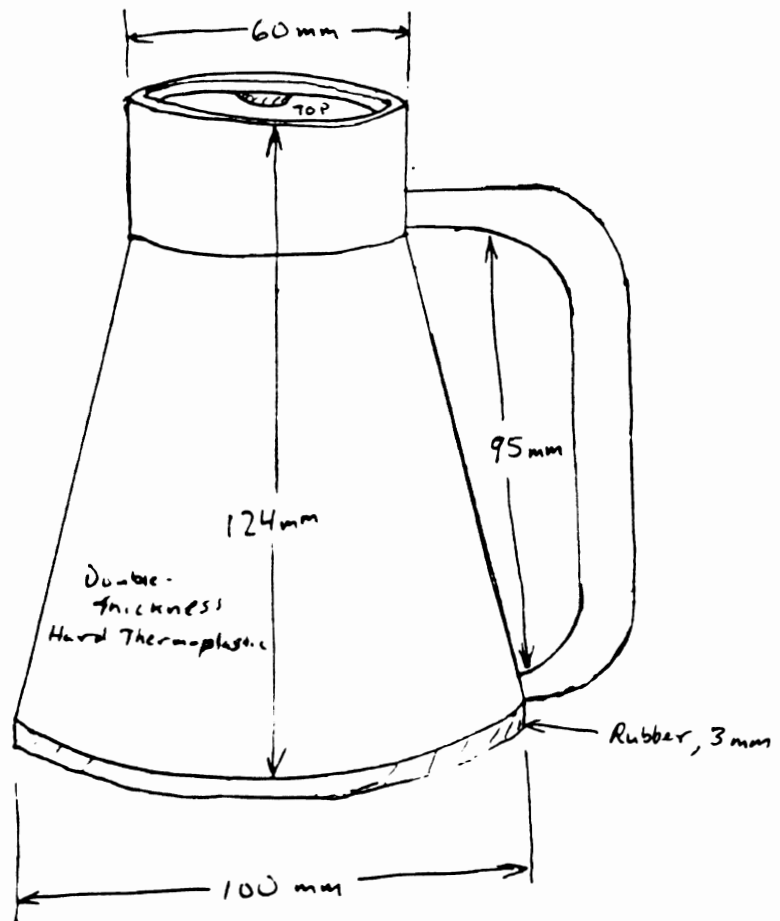
● 9, Strong Relationship
 ○ 3, Moderate Relationship
 △ 1, Weak Relationship

Hard Thermoplastic

Aluminum
 2024-T3
 6061-T6
 7075-T6

= 1567
 → Decisions on material types are important.

Product Design Matrix.



New Cup

Appendix C

QFD Course Masters For Overhead Slides

Course Objectives

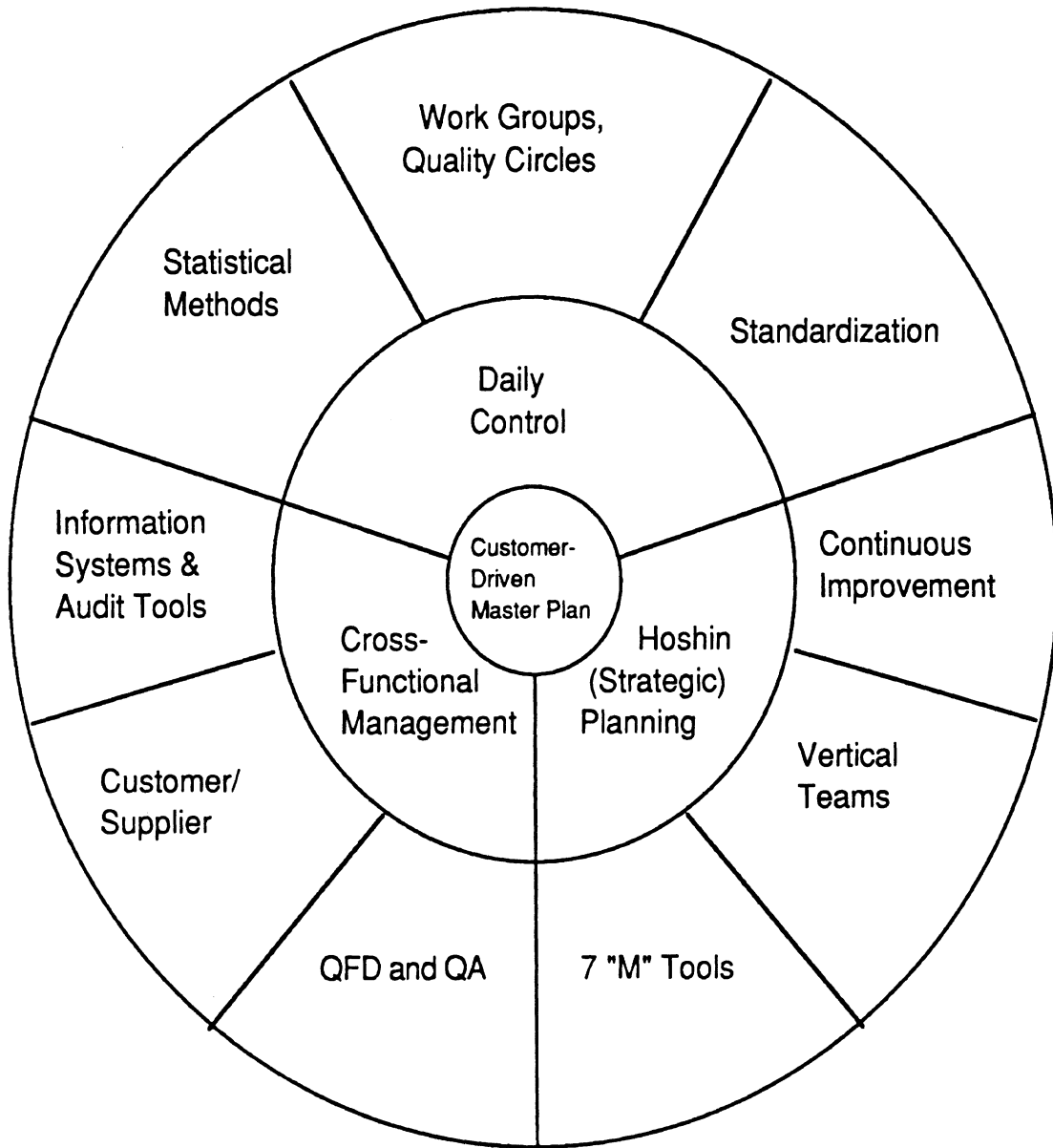
- **Introduce Quality Function Deployment to those associated with ship design and construction in the U.S.**
- **Give potential Quality Function Deployment users experience with the specific mechanics of the QFD process.**
- **Provide potential Quality Function Deployment users QFD experience within a shipbuilding context.**
- **Provide potential Quality Function Deployment users with additional references for QFD information and instruction.**

Definition Of QFD

- QFD is a disciplined process that facilitates the identification and deployment of customer wants and needs throughout an organization as a basis for product planning, development, and implementation.
- A customer is anyone who uses your goods or services. Customers can be internal or external to your organization.
- "Quality" does not just mean "conformance to specifications." "Quality" in this context represents those attributes that customers want or need in a specific product or service. These attributes are often qualitative rather than quantitative.

The History Of QFD

- The QFD methodology was conceived and first used as a formal discipline at Kobe Shipyard of Mitsubishi Heavy Industries in 1972.
- QFD has been adopted by most world-class product and service suppliers as part of the Total Quality Management (TQM) philosophy.
- QFD was introduced to the U.S. in 1983. Some U.S. companies that have made QFD an integral part of doing business are Motorola, Ford, Rockwell International, IBM, and Florida Power and Light.



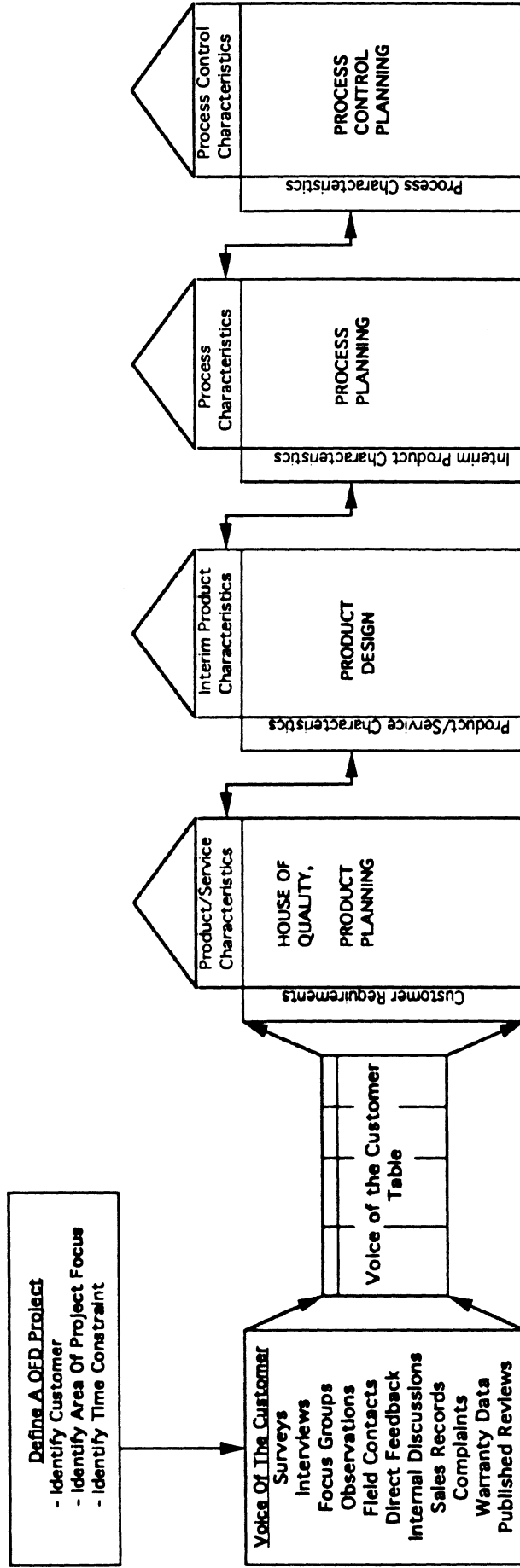
QFD Benefits

- Enhances internal and external communications
- Improves quality
- Increases customer satisfaction.
- Reduces product development time by 30-50%
- Lowers start-up costs by 20-60%
- Reduces the number of design changes by 30-50%
- Reduces warranty claims by 20-50%
- Fosters cross-function team building
- Facilitates simultaneous product and process design
- Improves design for production
- Allows lower pricing because of lower development costs
- Removes bottlenecks in product development and implementation
- Builds a database for future product development
- Provides a means of evaluating your competition
- Identifies key areas in product development where time and effort can be focused to gain a competitive advantages

TERMINOLOGY

- House of Quality (generic)= Product Planning Matrix (generic)= A-1 Matrix (GOAL/QPC)
- Customer Requirements (NSRP)= Quality Requirements (Florida Power and Light, FP&L)= Demanded Quality (Akao and GOAL/QPC)= Required Quality (American Supplier Institute, ASI)
- Product/Service Characteristics (NSRP)= Technical Requirements (Technicomp)= Quality Elements (FP&L)= Quality Characteristics (Akao and GOAL/QPC)= Quality Items (ASI)
- Interim Product/Part Characteristics (NSRP)= Part Characteristics (Technicomp)= Mechanisms and Unit Parts (Akao)= Systems and Unit Parts (ASI)= Mechanisms, Systems, Sub-Systems, Parts, Components, Raw Material (GOAL/QPC)
- Process Control Characteristics (NSRP)= Process Control Methods (Technicomp)

Underlined terminology will be used in this course.



The Four-Matrix QFD Process.

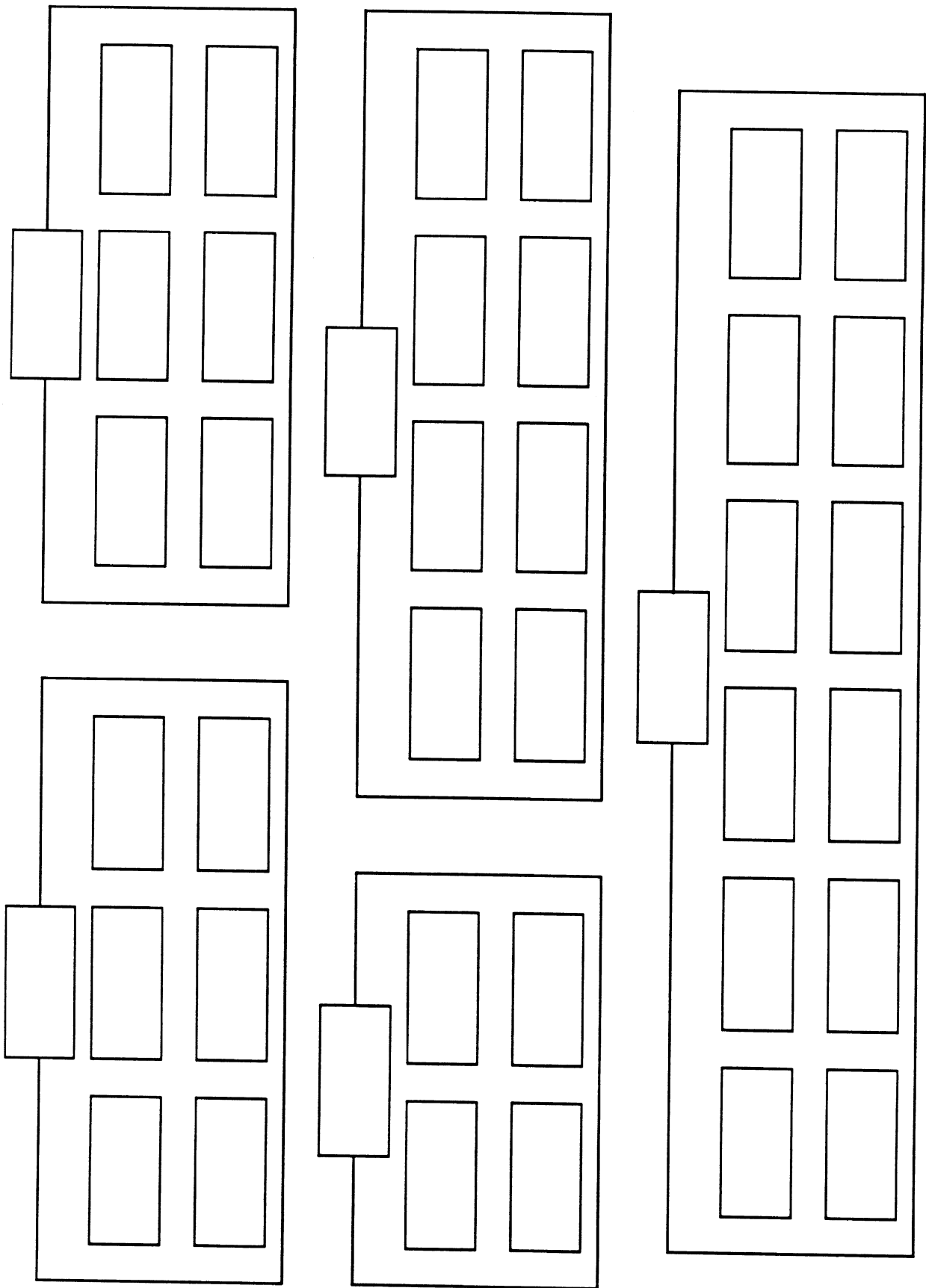
Requirements For QFD Success

- Management commitment for at least a QFD pilot project is a minimum requirement.
- Active support and participation of management is ideal.
- Project team diversity is essential. The team may include members from:

- Design/Engineering
- Process Engineering
- Production Engineering
- Production
- Quality Assurance
- Marketing
- Sales

Depending on the type of QFD project, the team might also include:

- Purchasing
 - Distribution
 - Accounting
 - Finance
 - Human Resources
 - Suppliers
 - Customers
- Project team members must have a basic understanding of QFD and must be committed to the QFD process.



Affinity Diagram.

Affinity Example

Customer (mechanic) requirements for a shipbuilding work package:

- Bill of material
- Any special tools required
- Complete work sketches
- Definition of global reference lines to be used
- All material for production of the interim product
- All necessary production control documentation
- Accurate pieces
- Accurate list of material
- All pieces with proper ID
- All necessary inspection documentation
- Accurate work instructions
- Proper reference lines or marks on all pieces
- Work sketches without unneeded information

Affinity Example

Correct Parts

- All material for production of the interim product
- Accurate pieces
- All pieces with proper ID
- Proper reference lines or marks on all pieces

Correct Bill of Material

- Accurate list of material
- Any special tools required

Correct Instructions and Sketches

- Complete work sketches
- Definition of global reference lines to be used
- Accurate work instructions
- Work sketches without unneeded information

Correct Work Documentation

- All necessary production control documentation
- All necessary inspection documentation

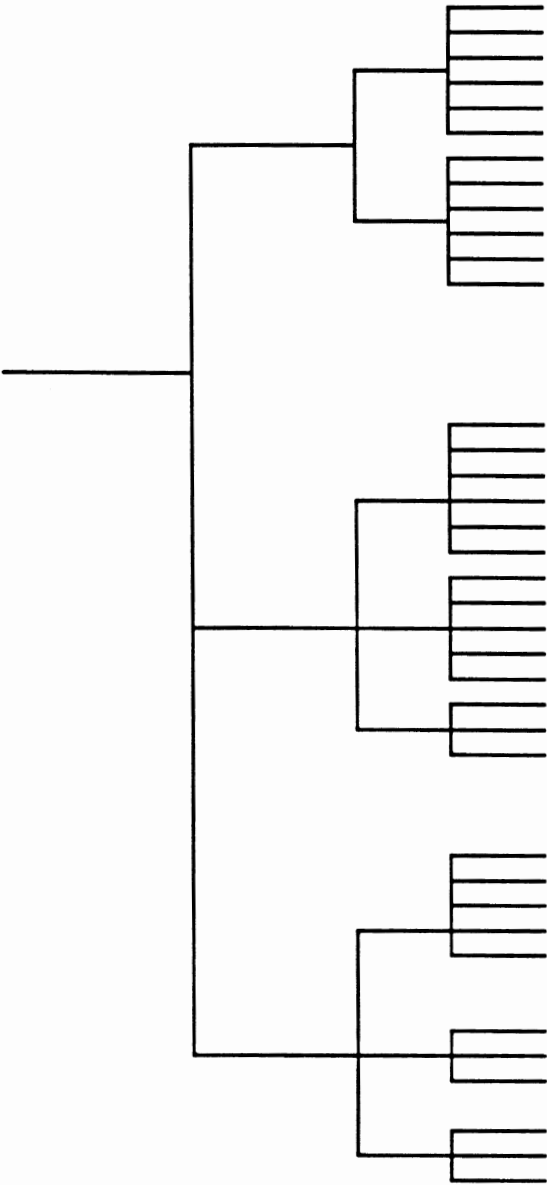
Correct Tools

- Any special tools required

Less Detailed,
More Important



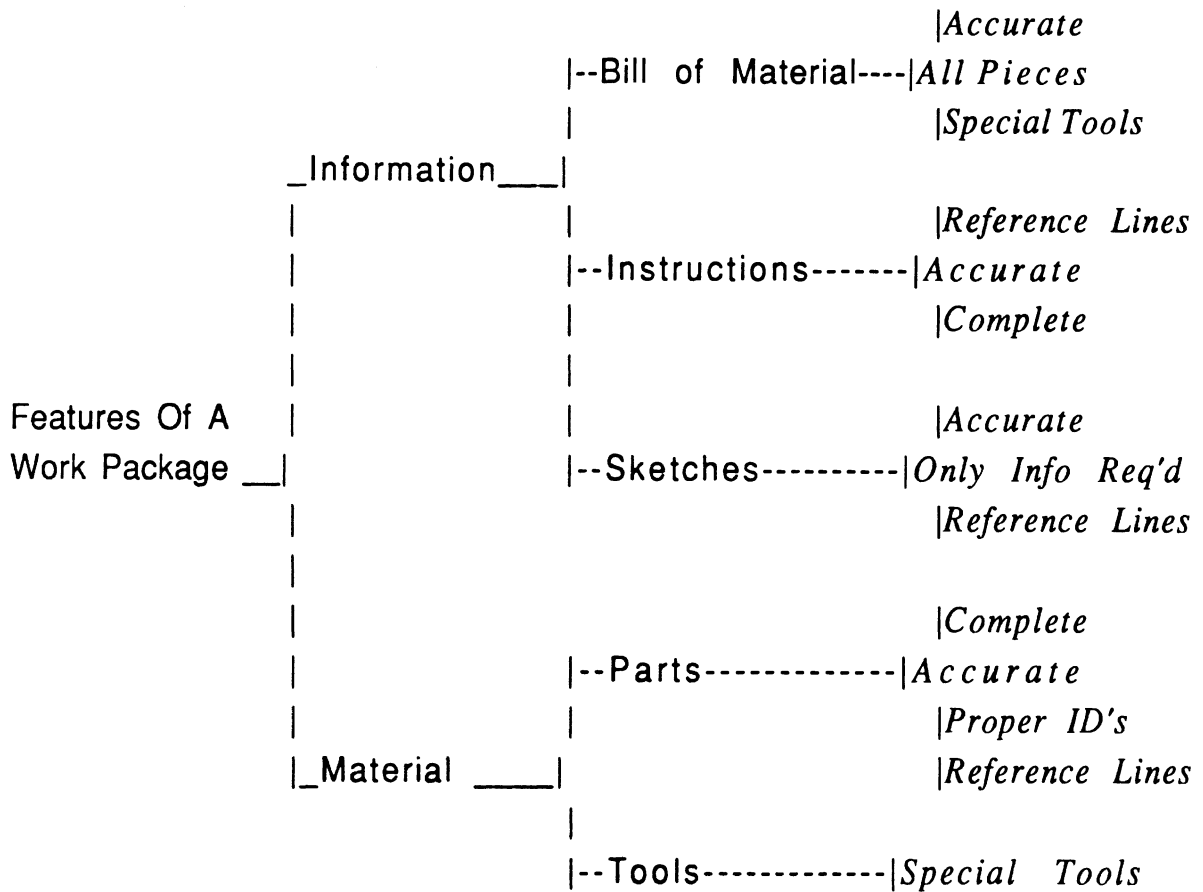
More Detailed,
Less Important

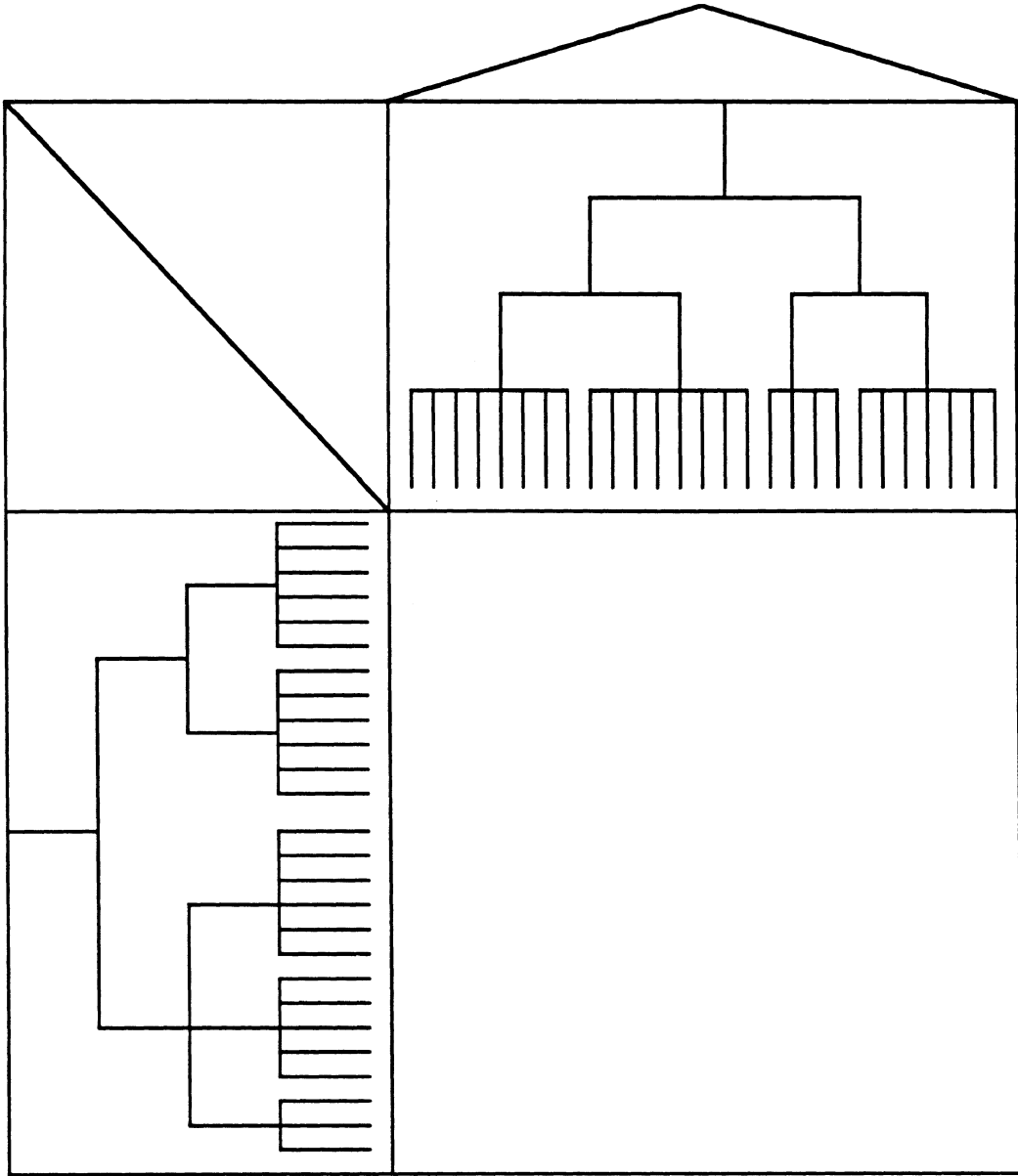


Tree Diagram.

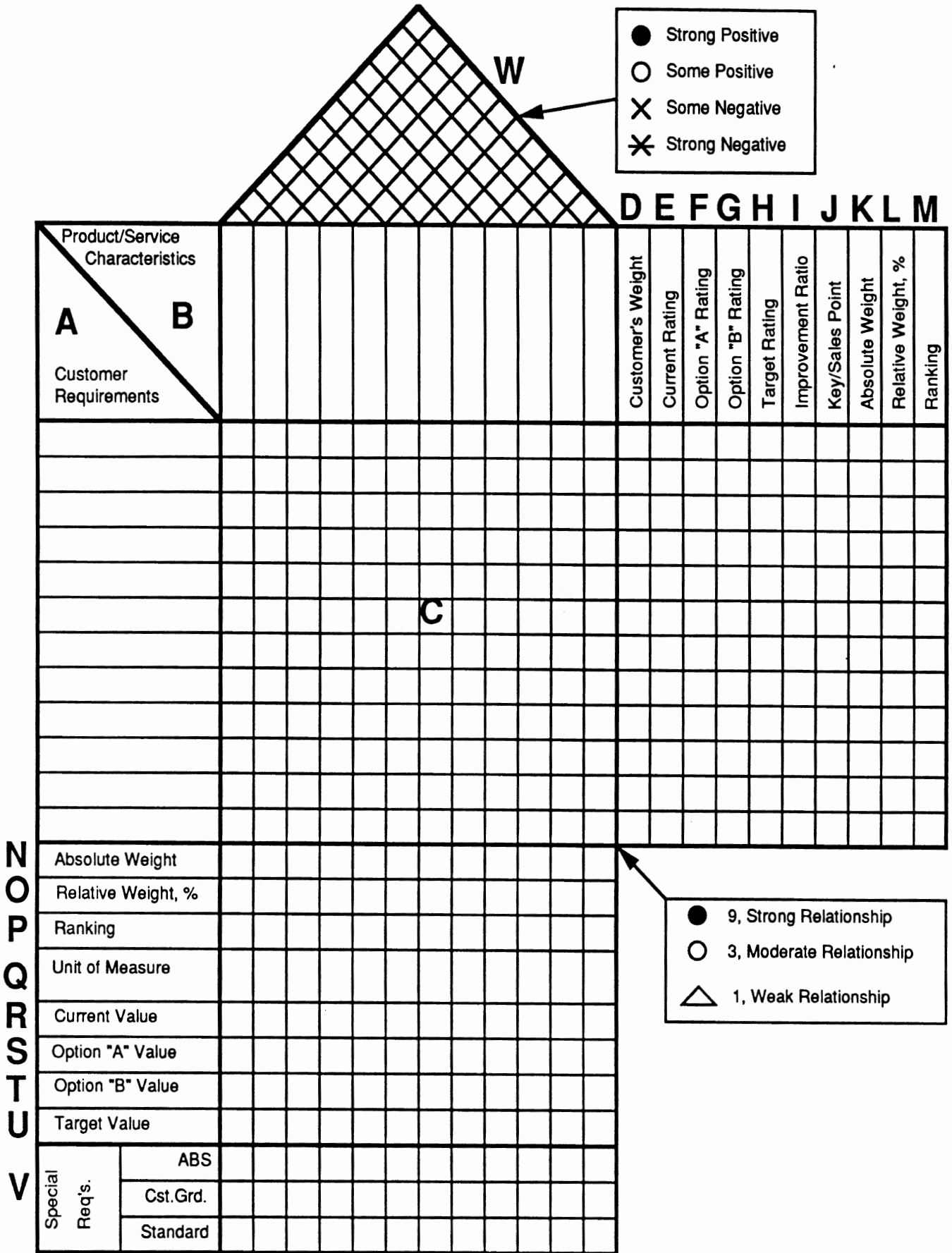
Example Tree Diagram

Less Detail-----More Detail
 More Important-----Less Important

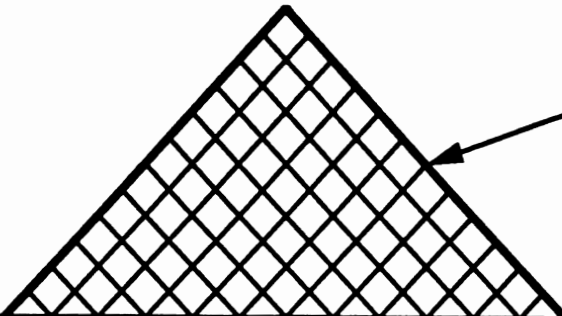




Tree Diagrams Related To A QFD Matrix.



House Of Quality/ Product Planning Reference Matrix.



●	Strong Positive
○	Some Positive
×	Some Negative
✖	Strong Negative

Product/Service Characteristics											Customer's Weight	Current Rating	Option "A" Rating	Option "B" Rating	Target Rating	Improvement Ratio	Key/Sales Point	Absolute Weight	Relative Weight, %	Ranking	
	Customer Requirements																				
			△			○															
				○				○		△											
	○							△		○											
		○		○		○															
			○		○																
			○		○			△													
	△									○	○										
		○			△			○													
		○		△				○													
										○	△										
Absolute Weight																					
Relative Weight, %																					
Ranking																					
Unit of Measure																					
Current Value																					
Option "A" Value																					
Option "B" Value																					
Target Value																					
Special Req's.	ABS																				
	Cst.Gr.																				
	Standard																				

●	9, Strong Relationship
○	3, Moderate Relationship
△	1, Weak Relationship

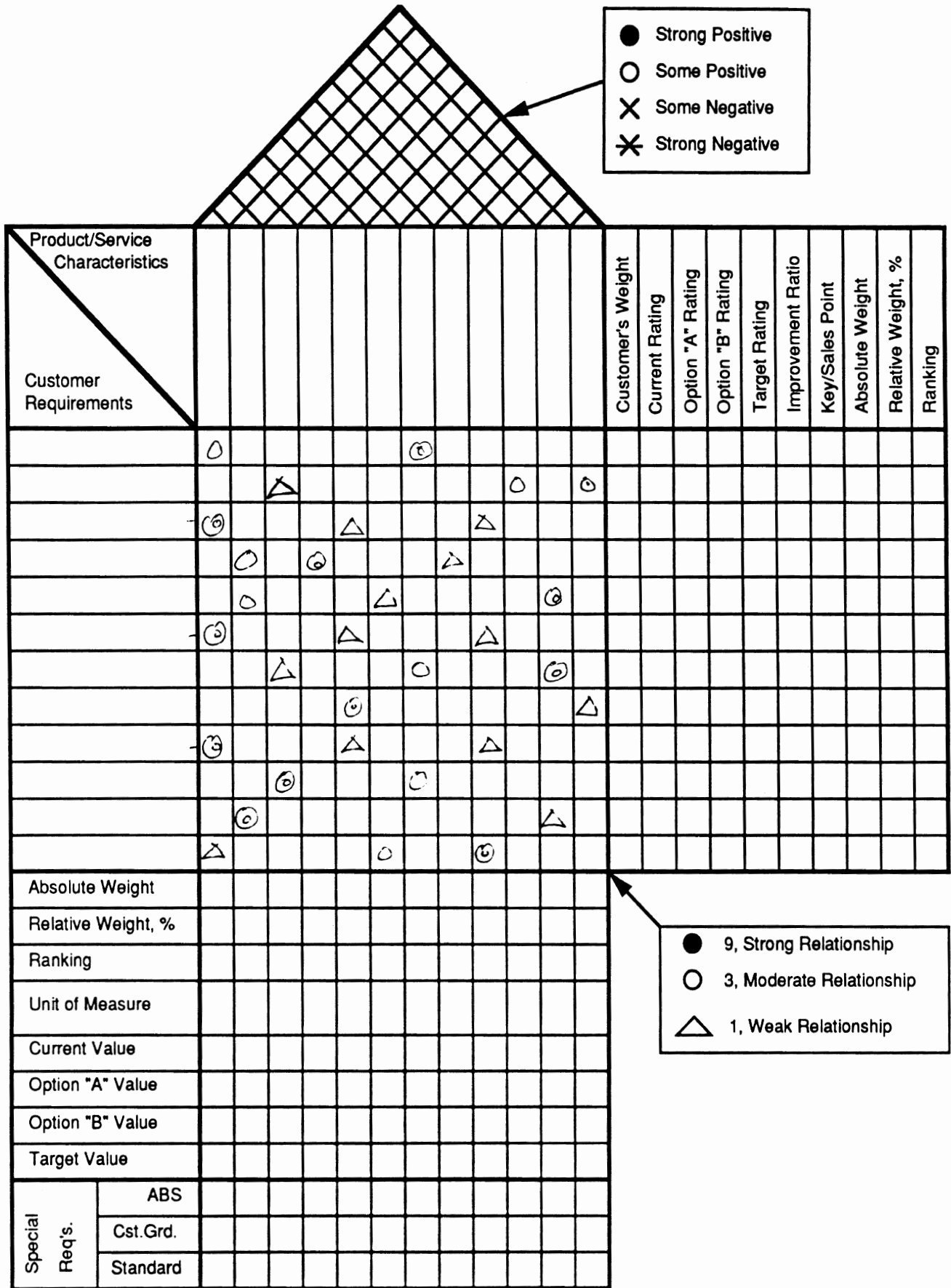
The House Of Quality/Product Planning Matrix.

Product/Service Characteristics		Customer Requirements										Customer's Weight									
												Customer's Weight	Current Rating	Option "A" Rating	Option "B" Rating	Target Rating	Improvement Ratio	Key/Sales Point	Absolute Weight	Relative Weight, %	Ranking
		△			○		○														
			○		△			○													
				△		○			○												
		○	○	○																	
			△					○		○											
				○				△		△											
					○				○												
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			△					△													
Absolute Weight																					
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	Standard																				

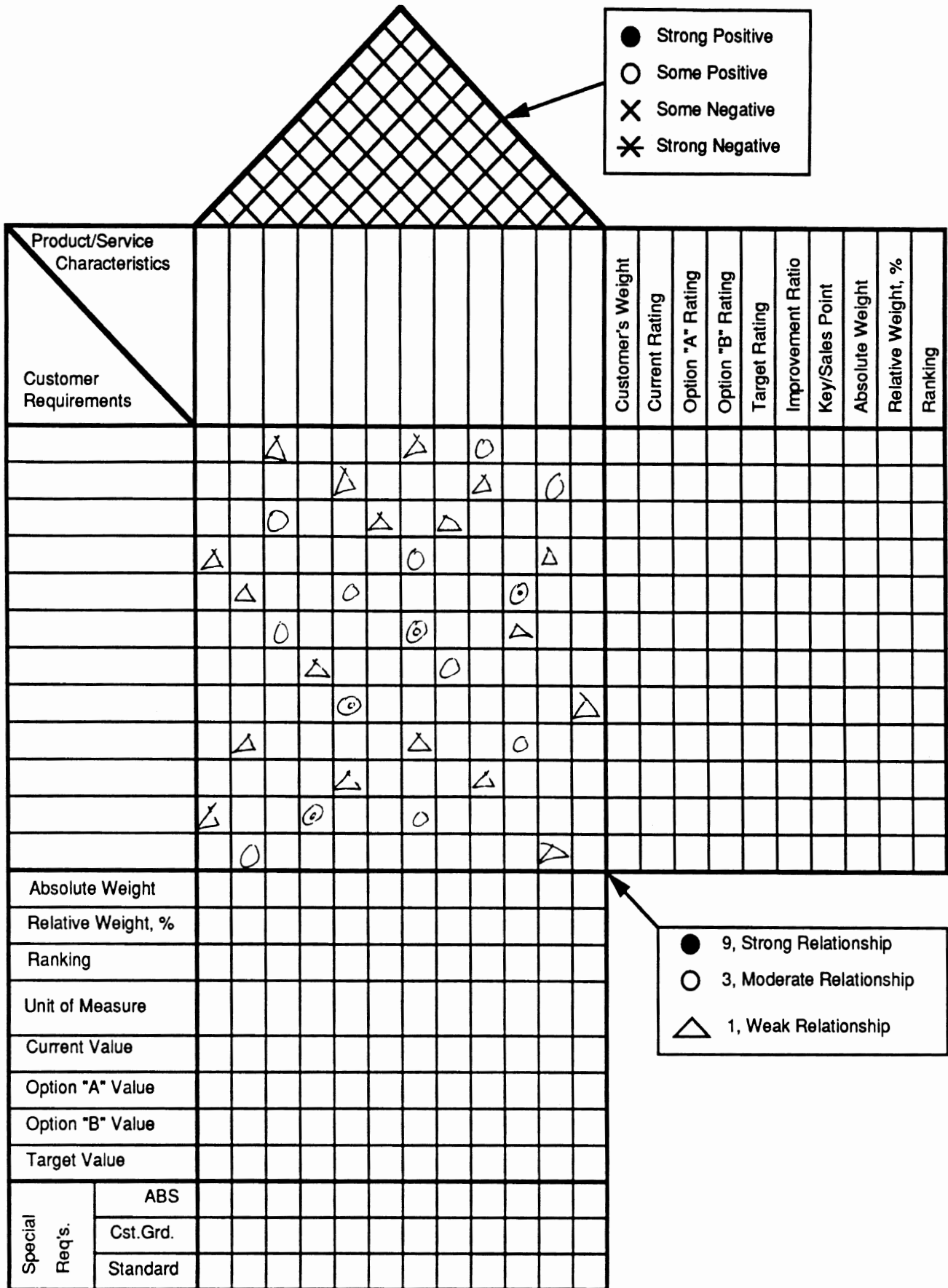
- Strong Positive
- Some Positive
- × Some Negative
- * Strong Negative

- 9, Strong Relationship
- 3, Moderate Relationship
- △ 1, Weak Relationship

The House Of Quality/Product Planning Matrix.



The House Of Quality/Product Planning Matrix.



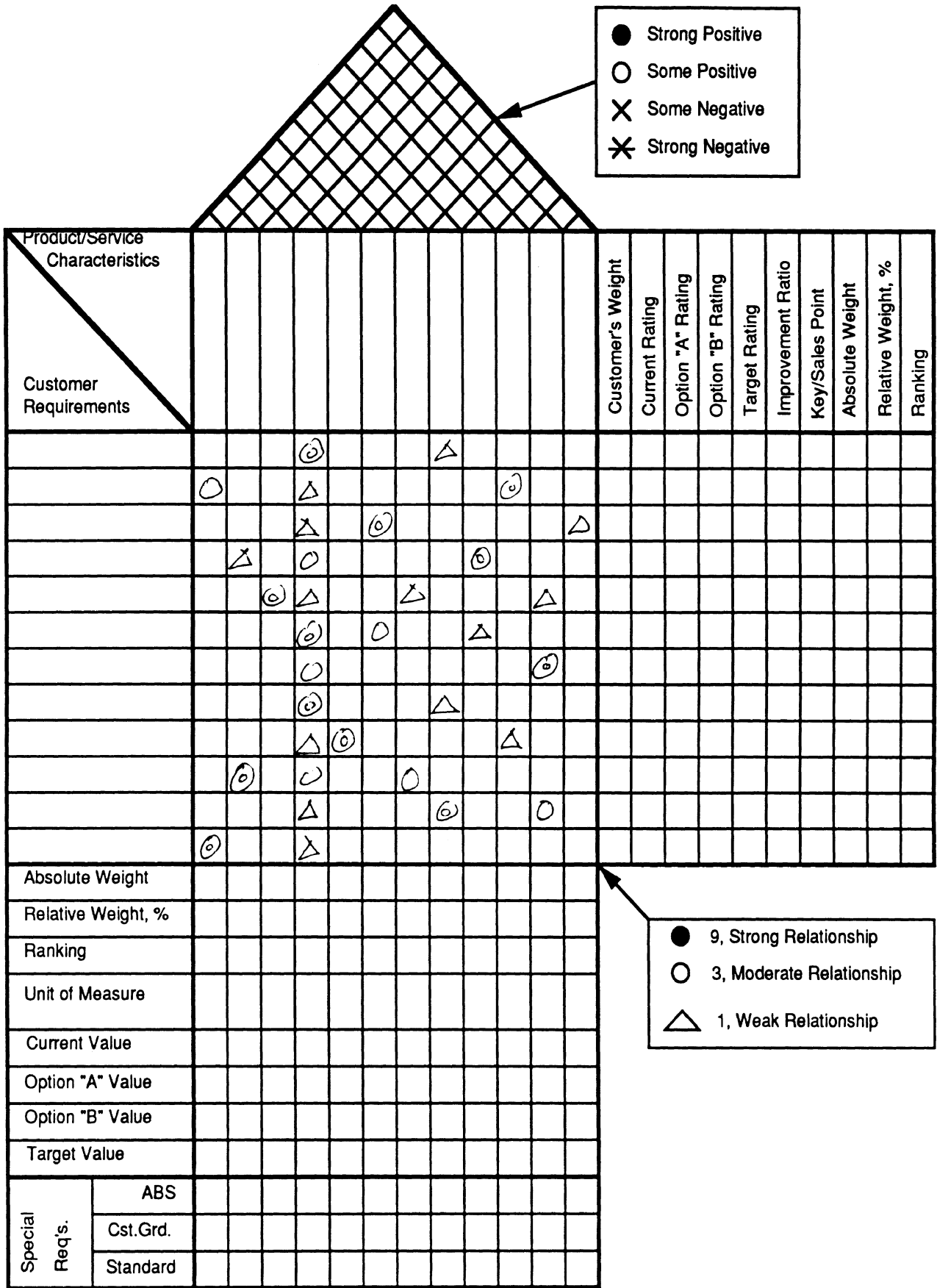
The House Of Quality/Product Planning Matrix.

Product/Service Characteristics												Customer's Weight	Current Rating	Option "A" Rating	Option "B" Rating	Target Rating	Improvement Ratio	Key/Sales Point	Absolute Weight	Relative Weight, %	Ranking
		Customer Requirements																			
		⊙																			
		△	⊙																		
			⊙																		
			△	⊙																	
					△	⊙	⊙														
					⊙	△															
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										△	⊙	△									
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Special Req's.	ABS																				
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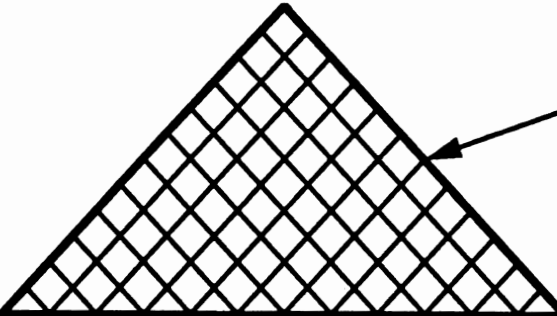
- Strong Positive
- Some Positive
- × Some Negative
- ✱ Strong Negative

- 9, Strong Relationship
- 3, Moderate Relationship
- △ 1, Weak Relationship

The House Of Quality/Product Planning Matrix.



The House Of Quality/Product Planning Matrix.



●	Strong Positive
○	Some Positive
×	Some Negative
✖	Strong Negative

Product/Service Characteristics											Customer's Weight	Current Rating	Option "A" Rating	Option "B" Rating	Target Rating	Improvement Ratio	Key/Sales Point	Absolute Weight	Relative Weight, %	Ranking
	Customer Requirements																			
			△																	
				△	○					○										
		○							△											
			○	△																
	△							△		○										
				△																
					○															
									○											
	○	△	△	○	△	○	○	○	△	○	△	△								
				○																
			△							○										
	○										○									
Absolute Weight																				
Relative Weight, %																				
Ranking																				
Unit of Measure																				
Current Value																				
Option "A" Value																				
Option "B" Value																				
Target Value																				
Special Req's.	ABS																			
	Cst.Gr.																			
	Standard																			

●	9, Strong Relationship
○	3, Moderate Relationship
△	1, Weak Relationship

The House Of Quality/Product Planning Matrix.

Having completed a House Of Quality, you should have:

- **a very good idea of the relative importance of specific customer requirements and associated product or service characteristics,**
- **identified areas where a competitive advantage might be gained, and where compromises might have to be made in product development, and**
- **developed target values for product/service characteristics, and methods for measuring whether these requirements are being met.**

Perceptions Of "Quality"

- One-Dimensional Quality: Features that customers specifically request. If these features are present, customers are pleased. If these features are absent, customers are not satisfied.
- Expected Quality: Features that are considered essential and, therefore, are often taken for granted and not specifically requested. If these features are present, customers are satisfied. If these features are absent, customers are not satisfied.
- Exciting Quality: Features that customers do not realize are possible. They may relate to new technology. Because customers do not realize that these features are possible, they do not specifically request them. If these features are present, customers are surprised and very pleased. If these features are absent, customers are not unsatisfied.

Voice Of The Customer Sources

	Information	Complexity	Sample	Bias	Time	Cost
INTERVIEWS						
Face to Face	Direct	Medium	Small	No	High	High
Telephone	Direct	Medium	Small	No	High	High
FOCUS GROUPS	Direct	High	Small	No	High	High
OBSERVATIONS						
Clinics	Direct	High	Small	No	High	High
Displays	Direct	High	Small	No	High	High
FIELD CONTACTS						
Sales Meetings	Direct	Low	Small	Yes	Low	Low
Service Calls	Direct	Low	Small	Yes	Low	Low
Trade Shows	Direct	High	Medium	Yes	High	High
DIRECT VISITS	Direct	High	Medium	Yes	High	Medium
EMPLOYEE FEEDBACK	Direct	High	Medium	Yes	High	Medium
SURVEYS						
Mail	Indirect	Medium	Large	Yes	High	High
Telephone	Direct	Medium	Medium	Yes	High	High
Comment Cards	Indirect	Medium	Large	Yes	High	Low
Point of Purchase	Indirect	Medium	Large	Yes	High	Low
SALES RECORDS						
Monthly Sales	Indirect	Low	Large	Yes	Low	Low
Sales Contacts	Indirect	Low	Large	Yes	Low	Low
Replacement	Indirect	Low	Large	Yes	Low	Low
Part Sales	Indirect	Low	Large	Yes	Low	Low
COMPLAINTS						
Letters	Direct	Low	Large	Yes	Low	Low
Cards	Direct	Low	Large	Yes	Low	Low
WARRANTY DATA						
Service Records	Direct	Low	Large	Yes	Low	Low
Service Workers	Direct	Low	Large	Yes	Low	Low
Return Cards	Direct	Low	Large	Yes	Low	Low
TOLL-FREE HOTLINE	Direct	Low	Large	Yes	High	High
PUBLICATIONS						
Government	Indirect	Low	Large	Yes	Low	Low
Independent	Indirect	Low	Large	Yes	Low	Low
Trade Journals	Indirect	Low	Large	Yes	Low	Low
Consumer	Indirect	Low	Large	Yes	Low	Low

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**Once a VOCT has been completed,
the project team should have:**

- a list of specific, singular customer requirements that are traceable back to specific voice of the customer statements;
- a mutual understanding of these customer requirements;
- captured customer-provided information that can be referenced in creating other QFD matrices, such as functions and failure modes.

The customer requirements identified can now be used as the basis for an affinity diagram, a tree diagram, and, finally, the customer requirement axis of the product planning matrix.

When Is A QFD Project Complete?

Having completed the product planning matrix, the project team will have:

- gained significant understanding of what the customer wants,
- improved communication with the customer and within the supplier organization,
- established which product/service characteristics are important to meeting customer requirements,
- gained improved understanding of how well their product/service and the products/services of their competitors meet the needs of the customer, and
- identified areas where improvement in product/service characteristics could have a significant effect on customer satisfaction, sales, and competitiveness.

However, the project team may feel that additional detail is required in some areas, and/or that a detailed implementation plan is required to help translate customer demands into specific supplier organization actions.

Interim Product/ Part Characteristics			Interim Product			Interim Product					
			Interim Product		Interim Product	Interim Product		Interim Product			
Important Product/Service Characteristics	Target Value	Relative Weight	Part Characteristic	Part Characteristic	Interim Product Char.	Part Characteristic	Part Characteristic	Interim Product Char.	Part Characteristic	Part Characteristic	Interim Product Char.
Absolute Weight											
Relative Weight											
Target Value											

- 9, Strong Relationship
- 3, Moderate Relationship
- △ 1, Weak Relationship

The Product Design Matrix.

Process Characteristics			Process "A"			Process "B"			Process "C"			Process "D"					
			Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic	Process Characteristic			
Important Interim Product/ Part Characteristics	Target Value	Relative Weight															
Absolute Weight																	
Relative Weight																	
Target Value																	

- 9, Strong Relationship
- 3, Moderate Relationship
- △ 1, Weak Relationship

The Process Planning Matrix.

Part/Interim Product ID	Process Function	Potential Failure Mode	Potential Effects	Potential Causes	Frequency	Degree of Influence	Criticality	How Detected	Suggested Countermeasure	Results

Failure Mode Effects Analysis.

