



## QUALITY FUNCTION DEPLOYMENT IN MAINTENANCE WORK PLANNING PROCESS

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### ABSTRACT

Maintenance systems have a tremendous impact on organizations' ability to meet their objectives. The realization of this impact has directed the attention to maintenance quality and performance. It also called on the use of total quality management tools for improving maintenance quality. The purpose of this paper is to customize the techniques of quality function deployment (QFD) for designing effective maintenance job plans and demonstrate its use in the design of a valve overhaul at a local refinery.

In this study engineers from operations are used as external customers and maintenance crafts as internal customers to identify the job technical and planning requirements. Then QFD process planning matrices are used for developing several alternative job design concepts. Then based on a simple decision criterion the design concept that closely meets customer requirements is identified. The result of the analysis is a well-planned maintenance job that improves the refinery operations.

**Keywords:** Maintenance work planning, quality function deployment, valve overhaul.

المخلص

## 1. INTRODUCTION

Maintenance systems play a key role in achieving organizational goals and objectives. They contribute to reducing cost, minimizing equipment down time, improving quality and providing reliable equipment that are safe and well configured to operate. Traditionally maintenance is considered as a secondary system serving production. Not until recently its role has been recognized [Duffuaa *et al* 1999, Kelly,1989, Ben Daya & Duffuaa, 1995], and the need to improve maintenance jobs and processes has been focused on. In the past the quality of maintenance work has been controlled by:

- Lining up the best qualified crafts and trades
- Inspection of performed jobs
- Continuous training of maintenance personnel

[Ben Daya and Duffuaa, 1995] proposed several ways to link quality and Maintenance and also [Duffuaa and Ben Daya, 1995] has shown how the seven quality tools can be used to improve maintenance work. [Kelly, 1989] has outlined means and ways to treat and manage maintenance as a business function. Treating maintenance as a business function has directed the attention to maintenance planning and the effective utilization of resources. Also, it brought the quality of maintenance work at a sharp focus. This focus called for the use of the total quality management tools (TQM) in maintenance. These tools include statistical process control, benchmarking and quality function deployment. QFD is an adaptation of some of TQM tools. It is a planning technique that was borne in Japan as a strategy for assuring that quality is built into new processes. It helps an organization to take the “voice of the customers” and factor their wants and needs into the organization product and process planning. This technique has been applied in manufacturing and production areas and not utilized in maintenance [Day, 1993]. [Kutucuoglu *et al*, 2001] utilized the matrix structure of QFD to develop performance measurement systems in maintenance.

The QFD process uses matrices (sometimes called quality tables) to help organizations to satisfy their customer requirements. The first of these matrices is called the house of quality (HOQ). It displays the customers’ wants and needs along the left side of the matrix and the technical requirements to meet these wants along the top of the matrix. The HOQ has several sub-matrices joined together and they relate technical requirements, technical targets to customer needs. There is no agreement by QFD authorities in the terminology associated with parts of the HOQ, however there is an agreement on the purpose of the HOQ. Then a series of matrices is generated to address the whats (customer needs) with the hows (possible technical know how). Other matrices are developed to generate design concepts, evaluate them and propose process parameters to deliver or produce the best design concept that meets customer requirements. More information on QFD is available in [Cohen, 1995].

The purpose of this paper is to customize the techniques of quality function deployment (QFD) for designing effective maintenance job plans and demonstrate its use in the design of a valve overhaul at a local refinery. The rest of the paper is organized as follows: Section 2 presents the customer and technical requirements for planning a valve overhaul at a local refinery. Section 3 describes the QFD process planning and its use to design the maintenance job that meets customer and technical requirements. Section 4 concludes the paper.

## **2. CUSTOMER AND TECHNICAL REQUIREMENTS**

In this section the technical requirements for the maintenance job will be defined and presented. Each technical requirement will have several levels from which design concepts will be developed in section 3. In this study engineers from operations are used as external customers and maintenance crafts are utilized as internal customers to identify the job technical requirements.

### **2.1. The Maintenance Job**

The plant selected to conduct this study is a large refinery in the Eastern province of Saudi Arabia. The refinery has a large maintenance department with around 500 employees. The maintenance department has many jobs to perform such as valves overhauls and heat exchanger maintenance. In this project we focus on valves. The main function of a valve is to regulate and control the flow of fluids through pipes. The following types of flow describe the basic valve functions.

#### **2.1.1 Block flow**

The block flow function provides “completely on” or “completely off” flow control of a fluid in a piping system. This might be necessary to take a piece of equipment out of service for maintenance, while the rest of the unit remains in operations.

#### **2.1.2 Throttle flow**

To throttle flow in a piping system may increase or decrease the amount of fluid flowing in the system and can help to control pressure at points within the system. It also regulates the filling rate of the pressure vessel. Preventive reverse flow is necessary to avoid damage to a pump or a compressor.

There are many types of valves. The gate valve is the type most commonly used to block flow in a process plant. The gate valve shuts off flow by forcing the gate against the valve body seating surfaces, which creates a pressure-tight seal in both directions. The gate has many problems that arise at the lock of the valve, the control of the valve and the limit of fluid in the

pipe of the valve. The job selected for study is the overhaul of the critical value due to its importance in process operation. This job is extremely important for the operation of the refinery. To assure that such jobs are well planned and executed their technical requirements must be carefully identified. Examples of these requirements include priority, spare parts, skill level and tools.

## **2.2. Customer and technical requirements**

The data required for the QFD process analysis are customer requirements and job technical requirements. The customers' requirements are obtained from engineers in the refinery operations department. The technical requirements are obtained from experienced technicians and crafts at the maintenance department. The requirements are obtained through carefully designed questionnaires. Different types of questionnaires are designed for the engineers at the operations department and the technicians in the maintenance department. The operations engineers were asked to identify their requirements for the valve overhaul problems. The requirements identified by the operations engineers (external customers) are:

1. Quick response to the job.
2. Reliability of the valve for the process.
3. Good flow rate of the valve.
4. Timely overhaul (least duration).
5. Durability of the overhauled valve.
6. Minimal shut down.
7. Resistance to corrosion.

The internal customers (maintenance staff) are asked about their requirements for the job and when interviewed responded by:

1. Availability of spare parts.
2. Availability of support equipment.
3. Proper job standards.

The technical requirements of the job and their relationships to the customers' requirements are necessary for developing the job planning matrixes. The technical requirements for the maintenance job are obtained by surveying the maintenance technical staff. They specified the following are the necessary technical requirements:

1. Priority.
2. Skill Level.

3. Material quality.
4. Inspection.
5. Support Equipment.
6. Kit availability.

The levels of each of the above technical requirements are described in the coming subsections.

### *2.2.1 Priority*

The technical requirement for priority has two levels. In the first priority level jobs are done immediately. In the second level jobs can be delayed up to two days.

### *2.2.2 Skill level for manpower*

The manpower available at the maintenance department has three skill levels. The technical requirement for manpower has three levels. These levels are: level 1 (specialist) level 2 (foreman) and level 3 (craft). The specialist is expected to perform the highest job quality level followed by the foreman and then the regular craft.

### *2.2.3 Types of materials used in valve*

Materials used in the valve overhaul have drastic impact on the quality of the maintenance job. All Materials must meet specifications specified in the organization standard. The technical requirement for the material has three levels depending on material quality. These levels are level 1, level 2 and level 3 depending on the manufacturing and composition of the material. Level 1 is the highest quality followed by level 2 and then level 3.

### *2.2.4 Inspection*

Inspection is preformed to ensure the quality of the maintenance job. All valves require a certain degree of inspection before installation and during operation. Requirements for valve inspection and testing are covered in the organization standard. The level of inspection is determined by who performs the inspection. The manpower that performs the inspection has three types. The types are specialist, foremen and crafts. Based on the type of manpower, the technical requirement for inspection has three levels. Inspection is considered level 1 (top quality) if a specialist conducts it. Inspection is level 2 (second grade quality) if a foreman performs it and level 3 if a technician conducts it.

### 2.2.5 *Support Equipment*

Support equipment are cranes and transport equipment. The technical requirement for the support equipment has two levels. Level one when all support equipment are available all the time and level two when it's available most of the time.

### 2.2.6 *Kit Availability*

A kit is a set of spare parts grouped together to allow quick response for the maintenance job. The technical requirement for kit availability has two levels. Level one when the kit is available and level two when it's not available.

## 3. **QFD PROCESS ANALYSIS**

The QFD process analysis will be used to identify the maintenance job that meets the customer requirements identified in section 2.

Typical customers requirements are shown on the left in the horizontal portion of the matrix in Table 1. External and internal customers have identified these requirements. The relationship between customer requirements and technical requirements for each type of customer is shown in Table 1. The column adjacent to the customer requirements shows the importance ratings that customers attach to each of their requirements. These were obtained through surveys. Operations engineers and maintenance supervisors were asked to rate the importance on a scale 1 to 9 with 9 being "highly important". These ratings will be used to evaluate the relative importance of the customers' wants and needs. The numbers shown in the Table 1 are the averages of the ratings.

The symbols shown directly below the technical requirements indicate the presence and strength of relationship between the customer and technical requirements. The three symbols shown are those most commonly used in QFD analysis. The double concentric circle is used to show a strong relationship. A single circle represents a moderate relationship and a triangle is used for weak relationship. For example, the symbol at the intersection of the first row and first column signifies that the team would work to improve "priority" in order to respond to customer requirements "quick response to the job". The double circle means the team agreed that any action to improve the technical requirement of a valve would have a strong effect on the customers' requirement.

Targets are shown below the technical requirements in the last row of Table 1. These represent team judgments of the goals or ideals targets which maintenance department team must establish for each technical requirement to satisfy customers.

In essence, the QFD matrix captures the information, which will be used to design an effective job plan for valve overhaul. Design concepts or design alternatives for the maintenance job will be developed based on the levels of the technical requirements and their impact on the customer requirements.

### **3.1 Job Design Concepts For Maintenance Of A Valve**

A design concept is a selection of a level for each of the technical requirements to come up with a job design that best satisfies the refinery operation and maintenance department requirements. Next several alternative design concepts are presented. These concepts will be evaluated in order to select the design that meets external and internal customer requirements.

Concept 1 assigns level 1 for all technical requirements for the job. In other words the job should have priority 1, assigned specialized manpower, allocated top material quality, inspected by a specialist and both support equipment and kit are available.

Concept 2 assigns level 1 priority, level 2 manpower, level 1 material, level 2 inspection, level 1 support equipment and level 1 for kit availability.

Concept 3 assigns level 1 priority, level 3 manpower, level 3 material, level 3 inspection, level 2 support equipment and level 1 kit availability.

Concept 4 assigns level 2 priority, level 1 manpower, level 3 material, level 2 inspection, level 2 support equipment and level 1 kit availability.

Concept 5 assigns level 1 priority, level 3 manpower, level 2 material, level 3 inspection, level 1 support equipment and level 2 kit availability

Concept 6 assigns level 1 priority, level 2 manpower, level 2 material, level 2 inspection, level 1 support equipment and level 1 kit availability.

Concept 7 (The current practice for this job) assigns level 1 priority, level 2 manpower, level 2 material, level 2 inspection, level 2 support equipment and level 2 kit availability. The job design concepts with their level of technical requirements are summarized in Table2.

Table 1 Valve overhaul job-planning matrix

		Technical requirements							Current practice			
		Rating	Row#	Priority	Skill Level	Material Quality	Inspection	Support Equipment	Kit Availability	Poor	Good	Excellent
Operations Engineers requirements	Customer Requirements											
	1. Quick response to the job	8	1	⊕	○	Δ	○	○	⊕			
	2. Reliability of the valve	9	2	Δ	⊕	⊕	○	Δ	Δ			
	3. Good flow rate	9	3	Δ	⊕	⊕	○	Δ	Δ			
	4. Timely overhaul	8	4	○	○	Δ	Δ	⊕	⊕			
	5. Durability of the overhaul	9	5	Δ	⊕	⊕	○	Δ	Δ			
	6. Minimal shutdown	8	6	⊕	○	Δ	Δ	○	⊕			
	7. Resistance to corrosion	7	7	Δ	Δ	⊕	○	Δ	Δ			
*MSTR	1. Availability of the spare parts	9	8	Δ	Δ	⊕	Δ	Δ	⊕			
	2. Availability of support equipment	7	9	Δ	Δ	Δ	Δ	⊕	Δ			
	3. Proper job standard	8	10	Δ	⊕	Δ	Δ	Δ	Δ			
	<b>Targets</b>			9	9	8	7	7	8			

\* MSTR stands for maintenance staff technical requirements

⊕ Strong, ○ Moderate, Δ Weak

Table 2 Job design concepts

Technical Requirements	Design Concept						
	1	2	3	4	5	6	7 *
Priority	1	1	1	2	1	1	1
Manpower Skill	1	2	3	1	3	2	2
Materials types	1	1	3	3	2	2	2
Inspection	1	2	3	2	3	2	2
Support Equipment	1	1	2	2	1	1	2
Kit availability	1	1	1	1	2	1	2

Numbers in the cells represent the level of each requirement.

Numbers in first row are the design concept number.

\* concept 7 represent current practice.



### 3.2 Design Concepts Evaluation

The design concepts are evaluated using the design concepts evaluation matrix as shown in Table 3. This matrix helps in selecting the design concept that best satisfies the external and internal customers. The design concepts under consideration are listed across the top of this matrix. Concept requirements are shown on the left in the horizontal portion of the matrix. The column that is adjacent to the concept requirements from left shows the source of each requirement. For analysis, one concept is chosen as a datum or a reference. In this case, the current practice is selected as a datum. Each column is compared against the current practice for the concept requirements. If the concept is superior to the current design, it will be given a plus sign (+). However, it is given a minus sign (-) when the concept is worse than or minor to the current practice. It will be given same (S) if the design concept and the current practice have the same level for the requirement.

After the evaluation is completed, each column is totaled for the number of pluses, minuses, and sames. Concepts 1 and 2 have the greatest number of pluses, five pluses for concept 1 and three pluses for concept 2. Concept 1 has one same and does not have any minuses while concept 2 has three sames and no minuses. The QFD process analysis identifies the concept that best meets the external and internal customers requirements. It is clear that without detailed analysis concept 1 is the best design concept that meets customer requirements, since it has the best level for every requirement. However the method in this section revealed that concept 2 is the second best followed by concept 6. The results indicate that a room exists for improving the current practice by adopting either concept 1, 2 or 6.

Table 3 Design concepts evaluation

Concepts requirements	Design concepts						
	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	
Priority	S	S	S	-	S	S	
Skill Level	+	S	-	+	-	S	
Material Quality	+	+	-	-	S	S	
Inspection	+	S	-	S	-	S	
Support Equipment	+	+	S	S	+	+	
Kit Availability	+	+	+	+	S	+	
Totals	+	5	3	1	2	1	2
	-	0	0	3	2	2	0
	S	1	3	2	2	3	4

#### 4. CONCLUSION

In this paper a brief description of QFD has been given. QFD planning matrices has been customized for designing a maintenance job plan. Engineers from the operations department at the refinery were used as external customers to identify their requirements and maintenance staff are employed as internal customers to identify technical and planning requirements for the job.

The set of matrices that relate customer requirements to technical requirements are identified and used in the design of the job plan. Several maintenance job design concepts have been developed and a simple selection procedure is used to obtain the best. The result indicted that there are at least three job design concepts that are superior to the current practice.

QFD has proven to be an effective tool for planning and deploying maintenance work. It also aids in providing an effective link between operations and maintenance and reduces the traditional conflict between them and fosters a good environment for teamwork. However, prior to applying QFD a need exists for an awareness program to help members of the organization appreciate the benefits that could result from QFD.

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