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Paper Organizers International: A Fictitious Six Sigma Green Belt Case Study. I

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ABSTRACT

"Six Sigma" management is in vogue in many of the world's largest and most successful corporations. However, for all of its popularity, there is much confusion as to the exact structure of a Six Sigma project. The purpose of this article is to present the first part of a detailed, step-by-step case study of a simple Six Sigma Green Belt project. This part of the case study presents the Define and Measure phases of the define-measure-analyze-improve-control (DMAIC) method for improving a process.

Key Words: *Six Sigma; Case study; Green Belt; Define-measure-analyze-improve-control method*

DEFINITION OF SIX SIGMA MANAGEMENT

"Six Sigma" management is the relentless and rigorous pursuit of the reduction of variation in all critical processes to achieve continuous and breakthrough improvements that impact the bottom-line or top-line of the organization and increase customer satisfaction, commitment, and loyalty. It is an organizational initiative designed to create manufacturing, service and administrative processes that produce no more than 3.4 defects per million opportunities (DPMO). The improvement method employed in Six Sigma initiatives to achieve this high standard of quality is called the DMAIC method, or the define-measure-analyze-

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improve-control (DMAIC) method. The elements of each step of the DMAIC method are shown below:

(1) *Define phase*: The define phase establishes the rationale for a Six Sigma project. This requires understanding the relationships between suppliers-inputs-process-outputs-Customers (SIPOC), gathering and analyzing "Voice of the Customer" data (that is, identifying the issues or concerns important to customers, called critical-to-quality (CTQ) variables, and preparing a business case (rationale for doing the project) with a project charter.

(2) *Measure phase*: The measure phase involves studying and understanding the CTQs. This requires developing operational definitions for each CTQ variable (develop definitions for each CTQ that have the same meaning to all users of the definition), performing a Gauge Repeatability and Reproducibility (R&R) study for each CTQ (determine if the measurement system is appropriate for the needs of the study), and establishing baseline capabilities for each CTQ. Additionally, the measure phase involves determining key measures for upstream suppliers, inputs, and processes, and collecting baseline data for those measures, if they exist.

(3) *Analyze phase*: The analyze phase involves identifying the upstream Xs for each CTQ, operationally defining each X, performing a Gauge R&R analysis for each X, establishing a baseline for each X, controlling the Xs for each CTQ, identifying the major noise variables for each CTQ, and understanding the effect of the Xs on each CTQ. Data mining and screening experimental designs help determine the "vital few" Xs for each CTQ.

(4) *Improve phase*: The improve phase optimizes the relationship between the CTQs and "vital few" Xs. This requires designing experiments to understand the relationship between CTQs and high risk Xs and major noise variables, generating the actions needed to implement the optimal levels of the "vital few" Xs that optimize the spread, shape, and center of the CTQs, developing action plans, and conducting pilot tests of the actions.

(5) *Control phase*: The control phase involves locking-in the improvements from a Six Sigma project and transferring them to the process owner. This requires avoiding potential problems in Xs with risk management and mistake proofing, standardizing successful actions in respect to the Xs and CTQs by developing, documenting, and implementing process control plans for all high risk Xs and CTQs. Additionally, the control phase involves institutionalizing and leveraging successful pilot tests with other areas in the organization, and transferring ownership of the improved process, products, or services to the process owner.

It is a common practice to teach Six Sigma Black Belt training in 4 sessions of 5 days each separated by 3 weeks. The first week session covers the Define and Measure phases of the DMAIC model. The second week session covers the Analyze phase of the DMAIC model. The third week session covers more of the Analyze phase and the Improve phase of the DMAIC model. The fourth week session covers the Control phase of the DMAIC model and future steps. Green Belt training is covered in 2 sessions of 5 days each, separated by 3 weeks. This article focuses on the Define and Measure phases of a Six Sigma case study appropriate for the first week of Six Sigma Black Belt training.

This article distinguishes between Black Belt and Green Belt Six Sigma projects on the basis of *five* criteria. Green Belt projects tend to be less involved (e.g., they have one CTQ and few Xs), do not deal with political issues, do not require many organizational resources, do not require significant capital investment to realize the gains identified during the project, and utilize only basic statistical methods. On the other hand, Black Belt projects tend to deal with more complex situations that may involve two or more CTQs and many Xs, may involve substantial political issues, or are cross-functional in nature, require substantial organizational resources, may need substantial capital investment to realize the gains made during the project, and utilize sophisticated statistical methods. Candidates for Green Belt training are individuals who are able to dedicate approximately 25% of their time to project work. Often the project work is focused on processes within or related to the area in which they currently work. Ideally Black Belt candidates are those who will be able to dedicate 100% of their time to one or more Six Sigma projects.

This article assumes that the reader is familiar with all the tools and methods discussed in the paper, for example, Quality Function Deployment (QFD), Kano surveys, Gauge R&R studies, capability analysis, control charts, probability distributions, to name a few. Readers unfamiliar with the tools and methods discussed are referred to Breyfogle,[1] Gitlow,[2] and Gitlow, Oppenheim, and Oppenheim.[3]

BACKGROUND OF PAPER ORGANIZERS INTERNATIONAL

Purpose

The purpose of this article is to present the define and measures phases of a fictitious application of the DMAIC

Table 1

POI's Business Objectives and Indicators with Potential Six Sigma Projects

President		Director of Paper Shuffling Department		
Business Objectives	Business Indicators	Area Objectives	Area Indicators	Potential Six Sigma Projects
Increase the number of orders	# Orders/month (c-chart)	Increase the number of orders in PSD	# Orders in PSD/month (c-chart)	New customer promotions project
Increase the number of POI services (filing, organizing, etc.) utilized by each customer	1. Average # of services utilized per customer/quarter 2. Standard deviation of number of services utilized per customer/ quarter (x-bar and s chart)	Increase the number of services utilized by each customer in PSD	1. Average # of services utilized per PSD customer/quarter 2. Standard deviation of number of services utilized per PSD customer/quarter (x-bar and s chart)	Existing customer promotions project
Minimize production costs	Production costs/month (I and MR chart)	Minimize production costs in PSD	Production costs in PSD/month (Fig. 1:I& MR chart)	MSD quality project
Eliminate employee complaints	# of employee complaints/month (c-chart)	Eliminate employee complaints from PSD	# of employee complaints from PSD/month (c-chart)	Employee morale project

model to be used as an educational aid by those individuals interested in learning the structure of a simple Six Sigma project, called a Green Belt project. The fictitious case study is presented below.

The Company

Paper Organizers International (POI) offers a full range of filing, organizing, and paper shuffling services. To accomplish these tasks, POI purchases Metallic Securing Devices* (MSDs), staplers, hole punchers, folders, three-ring binders, and a full range of related products to serve its customers' paper handling needs. The employees, or internal customers, of POI use MSDs to organize piles of paper pending placement into folders or binders.

The Purchasing Department of POI has noticed an increase in complaints from employees in the Paper Shuffling Department (PSD) about MSDs breaking and failing to keep papers together. This creates opportunities for client papers to be mixed together. The Purchasing Department would like to improve the process for purchasing MSDs to eliminate complaints from employees in the PSD.

*The idea for a Six Sigma case study focusing on Metallic Securing Device (MSD) was adapted from Cordis Corporation's (A Division of Johnson and Johnson) Six Sigma training manuals which were developed by Oriel Inc. (Madison, WI). Metallic Securing Devices (MSDs) are paper clips.

Origin of the MSD Six Sigma Project

The POI's mission statement is "Put the Right Information in the right Place," RIP it! To accomplish this mission, POI has established a cascading set of business objectives and business indicators, which ultimately result in potential Six Sigma projects, see Table 1.

The monthly production costs in the PSD are shown on the Individuals and Moving Range chart in Fig. 1 below, and the next to last row in the fourth column in Table 1.

Figure 1 shows that production costs are stable (no special causes such as points beyond a control limit or too many runs up and down, etc.) in the PSD with an average monthly cost of $1,096,880.00 and a standard deviation of $116,672 ($\text{R}-\text{bar}/\text{d}_2 = 111,672/1.128$). Additionally, production costs are approximately normally distributed, see Fig. 2. Team members discovered that PSD management considers monthly production costs to be very high given the volume of work being processed by the department.

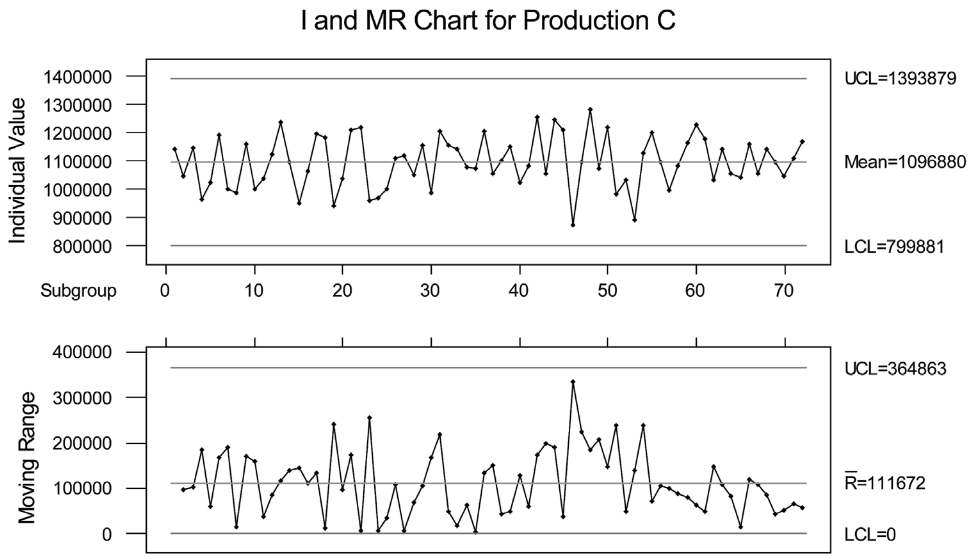

Figure 1. Individual and moving range chart of monthly production costs in the Paper Shuffling Department.

The four potential Six Sigma projects shown in the right-most column of Table 1 are prioritized for attention in Table 2. Table 2 is a QFD type matrix that weights the importance of each potential Six Sigma project to each of POI's business objectives.

The cell values are assigned by top management and are defined as follows: 0: No relationship, 1: Weak relationship, 3: Moderate relationship, and 9: Strong relationship. The Finance Department developed the importance weights for each business objective to maximize the impact of Six Sigma projects on the bottom-line of the organization. Consequently, the most critical project in respect to the business objectives is the MSD quality project, see 4.95 in the last row of Table 2. The Champion and Process Owner of the "MSD process" prepared an initial project charter. It presented the business case for the MSD quality project to the members of the MSD quality project team.

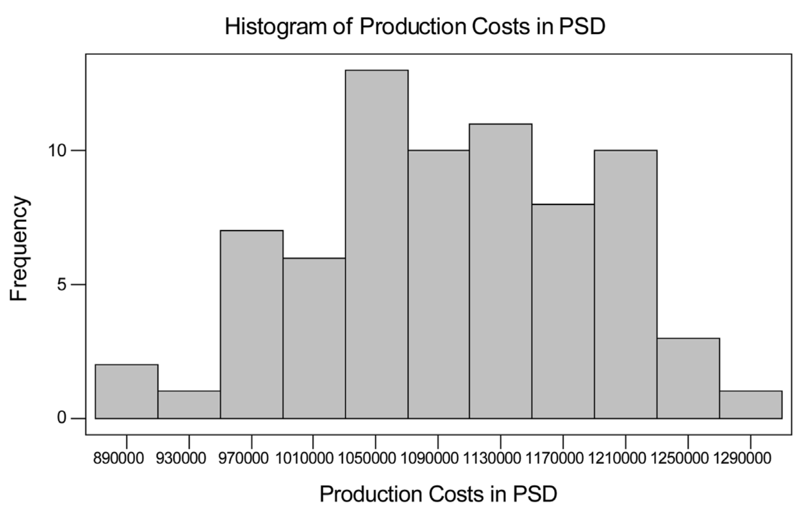

Figure 2. Distribution of monthly production costs in the PSD.

Table 2

Prioritization of Six Sigma Projects

Business Objectives	Weights	New Customer Promotions Project	Existing Customer Promotions Project	Metallic Securing Devices Quality Project	Employee Morale Project
		Potential Six Sigma Projects			
Increase the number of orders	0.35	3	3	0	0
Increase the number of POI services utilized by each customer	0.10	1	3	0	0
Minimize production costs	0.40	0	0	9	3
Eliminate employee complaints	0.15	0	0	9	9
Weighted average of potential six sigma projects		1.15	1.35	4.95	2.55

DEFINE PHASE

The define phase has three components: prepare a business case with a project charter, do a SIPOC analysis, and conduct a "Voice of the Customer" analysis.

Prepare a Business Case with a Project Charter

Preparing a business case with project charter requires team members to answer the following partially redundant questions. The redundancy in the questions helps team members distill the critical elements of the business case.

(1) *Question*: What is the name of the process?

Answer: The MSD Purchasing Process. The first step in the supply chain for the "MSD process" is the process for purchasing MSDs; hence, the first operation to be investigated by MSD quality project team members is the process for purchasing MSDs. Team members may study other factors that affect the quality of MSDs such as method of use or shelf life at a later time.

(2) *Question*: What is the aim of the process?

Answer: The aim of the purchasing process as it relates to this project is to purchase MSDs that improve the productivity and morale of the employees in the PSD.

(3) *Question*: What is the business case (economic rationale) for the project?

Question 3 is answered by addressing the following sub-questions.

(3a) *Question*: Why do the MSD project at all?

Answer: According to a judgment sample of three employees and two managers from the PSD, team members determined that MSDs that cannot withstand four or more bends are unacceptable because they are unlikely to remain intact throughout the paper shuffling processes and will not hold papers tightly; this is called durability. Defective MSDs create costs for POI, for example: (a) papers from different clients may get mixed together if not properly bound requiring additional processing time, (b) employees may have to use multiple MSDs for one project creating additional material costs, and (c) employees get frustrated and do not perform their jobs efficiently and productively increasing labor costs. Additionally, team members discovered that a large proportion of the boxes containing MSDs arrive to the PSD with five or more broken MSDs; this is called functionality. This creates additional processing costs for POI, for example, (a) increased unit costs and (b) frustrated and nonproductive employees and managers. Team members used the same judgment sample as above and determined that approximately 60% of individual MSDs do not meet durability criteria and 60% of MSD boxes do not meet functionality criteria; see the survey questionnaire in Table 3 and the data matrix in Table 4.

Table 3

Survey Questionnaire

Survey
Name:
1. Please estimate the percentage of MSDs that cannot withstand 4 or more bends
2. Please estimate the percentage of MSD boxes that contain greater than 5 broken MSDs

(3b) *Question*: Why do the MSD project now?

Answer: The PSD is experiencing very high monthly production costs, see Figs. 1 and 2. Also, internal customers, including managers and hourly employees, are submitting an increased number of complaints: 14 in the first quarter, 18 in the second quarter, and 32 in the third quarter, as recorded in the Purchasing Department's complaint log for the fiscal year 2000. There are 100 hourly workers in the PSD.

(3c) *Question*: What business objectives are supported by the MSD quality project?

Answer: The MSD project is most strongly related to the "minimize production costs (see Table 2)" and "eliminate employee complaints" business objectives, see Table 1.

(3d) *Question*: What are the consequences of not doing the project?

Answer: The consequences of not doing the project are decreased profit margins due to higher production costs and increased employee complaints due to frustration with materials.

Table 4

Survey Data

Survey Number	Response Q1	Response Q2
1	55	70
2	50	55
3	60	65
4	65	60
5	70	50
Average	60	60

(3e) *Question*: What projects have higher or equal priority?

Answer: At this time, the MSD quality project has the highest priority, see Table 2.

(4) *Question*: What is the problem statement? What is the pain?

Answer: Low quality MSDs create additional production costs and employee frustration.

(5) *Question*: What is the goal (desired state) for this project?

Answer: The Champion and Process Owner of the MSD process initially determined that a 100-fold improvement in MSD quality (durability and functionality) should be the goal for the Six Sigma project*. They derived the concept of a 100-fold improvement from Motorola's 1986 stated improvement rate of 10-fold every 2 years, or a 100-fold every 4 years during the kickoff of the Six Sigma effort. Since 100-fold improvement means the DPMO would decrease from 600,000 to 6,000, and a DPMO of 6210 represents a 4-sigma process, team members decided to use 4-sigma as the goal for the MSD project.

(6) *Question*: What is the project scope?

Question 6 is answered by answering the following sub-questions.

(6a) *Question*: What are the process boundaries?

Answer: The starting point for the project is when the Purchasing Department receives purchase orders from the PSD. The stopping point for the project is when the PSD places MSDs into inventory.

(6b) *Question*: What, if anything, is out-of-bounds?

Answer: The project team cannot change the way employees handle or use MSDs.

(6c) *Question*: What resources are available for the project?

Answer: The budget for the MSD project is $30,000.00. This includes estimated hourly salaries of

*A 100-fold improvement for this project is an arbitrary numerical goal and conflicts with Dr. W. Edwards Deming's 14 points for management. (3, p 19–36; 4; 5; 6).

project participants. Team members, Brian Mercurio, and Jeremy Pressman, are the only project participants that will incur additional job responsibilities as result of the project. Budget estimates show "opportunity cost" and "hard costs (see Table 5)." The estimated hard costs ($10,500) and total costs ($26,040) are less than the budget of $30,000.

(6d) *Question*: Who can approve expenditures?

Answer: Only the Process Owner, Dana Rasis, can approve expenditures.

(6e) *Question*: How much can the team spend beyond $30,000.00 without seeking additional authority?

Answer: Nothing.

(6f) *Question*: What are the obstacles and constraints of the project?

Answer: The team must work within a $30,000 budget and a 21 week time constraint.

(6g) *Question*: What time commitment is expected of team members?

Answer: Team members are expected to be present at weekly Friday morning meetings from 8:00 a.m. to 9:00 a.m. Team members are also expected to provide progress of project tasks at each meeting. Completion of project tasks may require additional hours of work per week.

(6h) *Question*: What will happen to each team member's regular job while he or she is working on the project?

Answer: If any, overtime hours will be compensated for team members and support staff. Note: The estimated rate for overtime labor is 1.5 times normal labor. Overtime labor is not included in the budget in Table 5.

(6i) *Question*: Is there a Gantt chart for the project?

Answer: A Gantt chart is shown in Table 6.

(7) *Question*: What are the benefits of the project?

Answer: The soft benefits of the project include eliminating complaints from the PSD and increasing employee morale. The hard (financial) benefits of the project are minimizing labor costs and material costs. The hard cost benefits are estimated below.

The labor costs of the current and proposed systems are presented in Table 7.

Hence, the annual savings on labor costs from improving MSD purchasing process is $296,900 ($300,000 − $3,100). The PSD incurs a 10% annual employee turn over. To capitalize on savings in labor costs, the department will now higher 4 new employees instead of 10 new employees, for a savings of 6 full-time employees ($296,900/$25 = 11,876 hr; 11,876/40 hr per week/50 weeks per year = 5.938 = ~6 employees saved). Note: Alternatively, the PSD may now serve more customers with their current employee base.

Table 5

Estimated Labor Costs for the Project

Name	Position	Estimated Salary/Hour	Expected Number of Hours Per Week	Expected Opportunity Costs for 21 weeks	Expected Hard Costs for 21 weeks (Direct Labor Costs)
Howard Gitlow	Champion	$100	2	$4,200	
Dana Rasis	Process owner	$50	2	$2,100	
Bettina Arguelles	Black belt	$50	5	$5,250	
Brian Mercurio	Team member	$25	10	$0	$5,250
Jeremy Pressman	Team member	$25	10	$0	$5,250
Lindsey Barton	Finance rep.	$45	2	$1,890	
Mary Montano	IT rep.	$50	2	$2,100	
Total				$15,540	$10,500

Table 6

Gantt Chart for the Metallic Securing Devices Project

		Week																				
Steps	Response	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Define	BA	X	X	X	X	X																
Measure	BA						X	X														
Analyze	BA								X	X	X											
Improve	BA											X	X	X	X	X	X	X				
Control	BA																		X	X	X	X

The material costs of the current system are shown in Table 8.

Hence, the annual savings on material costs from improving MSD purchasing process is $44,820 ($75,000 − $30,180). This yields an annual total hard benefit savings of $341,720.00.

(8) *Question*: What are the roles and responsibilities of team members?

Answer: The roles and responsibilities of team members are shown in Table 9.

Do a SIPOC Analysis

The second part of the define phase requires that team members perform a SIPOC analysis. A SIPOC analysis is a simple tool for identifying the Suppliers and their Inputs into a Process, the high level steps of a process, the Outputs of the process, and the Customers' segments interested in the outputs. A SIPOC analysis of POI's Purchasing Department is shown in Fig. 3. A Flow Chart is shown in Fig. 4.

Conduct a "Voice of the Customer" Analysis

The third part of the define phase involves team members collecting and analyzing "Voice of the Customer" data. Voice of the Customer data include verbal or written information collected from a sample of users, in a selected market segment. The questionnaire used to collect data from users of MSDs in the PSD is shown in Table 10.

Team members analyze the Voice of the Customer data by market segment (see column 1 of Table 11). Next, they use all the raw Voice of the Customer data points (see

Table 7

Labor Costs

100 employees in the Paper Shuffling Department
×40 hr/week/paper shuffling employee
×10% of time devoted to clipping
@ 400 hr/week devoted to clipping in PSD
×$25/hour/paper shuffling employee
$10,000/week devoted to clipping
×50 weeks/year
$500,000/year devoted to clipping
×0.60 defective clips (judgment sample estimate of durability of the current system). Broken clips are not selected for use on jobs. This makes 0.6 a conservative estimate of the percentage of defective clips in the current system. Note: This conservative estimate does not include problems arising from defective clips not detected until after they have been used and have caused failure on the job
$300,000/year on defective clipping for current system
×0.0062 defective clips (durability of the proposed system). Again, broken clips are not selected for use on jobs
$3100/year on defective clipping for proposed system

Table 8

Material Costs

100 employees in the paper shuffling department
×60 projects/week/paper shuffling employee
×50 weeks/year
@ 300,000 projects/year requiring 3,000,000 MSDs (10 clips per project on average)
×0.60 defective clips (judgment sample estimate of current system)
7,500,000[a] clips must be used to complete 300,000 projects
×0.01/clip
@ $75,000/year on clips in current system
×0.0062 defective clips (proposed system)
3,018,000[b] clips must be used to complete 300,000 projects
×.01/clip
@ $30,180/year on clips in proposed system

[a] Note: $1/(1-0.6) = 2.5$ clips needed to get a good clip. So, $3,000,000 \times 2.5 = 7,500,000$.
[b] Note: $1/(1-0.0062) = 1.006$ clips needed to get a good clip. So, $3,000,000 \times 1.006 = 3,018,000$.

column 2 of Table 11) to create affinity diagram [4, p. 83–89] themes, called focus points (see bold face numbers linking columns 2 and 3 in column 3 in Table 11). Next, team members identify the engineering issue underlying each focus point, called cognitive issues (see column 4 in Table 11). Then, team members convert each cognitive issue into one or more quantitative engineering variables, called CTQ variables (see column 5 in Table 11). Finally, team members develop technical specifications for each CTQ (see column 6 of Table 11).

A Kano questionnaire (see Table 12) is a tool used by team members to classify a set of CTQs (see column 1 in Table 12) into an appropriate Kano quality category (see columns 2 and 3 in Table 12) from a large sample of regular users of a product, service, or process. There are six common Kano categories.

1. One-Way (O)—User satisfaction is proportional to the performance of the feature; the lesser the performance, the lesser the user satisfaction, and the more the performance, the more the user satisfaction.
2. Must-Be (M)—User satisfaction is not proportional to the performance of the feature; the lesser the performance, the lesser the user satisfaction, but high performance creates feelings of indifference to the feature.
3. Attractive (A)—Again, user satisfaction is not proportional to the performance of the feature; low levels of performance create feelings of indifference to the feature, but high levels of performance create feelings of delight to the feature.
4. Indifferent (I)—User does not care about the feature.
5. Questionable (Q)—User's response does not make sense (e.g., delighted if feature is present and delighted if feature is absent).
6. Reverse [R]—User offers responses opposite the responses expected by individuals conducting the Kano survey (e.g., "do not like it" if feature is present and "delighted" if feature is absent).

Additionally, team members use a Kano questionnaire to classify CTQs into their appropriate Kano cost category (see column 4 in Table 12). There are three common Kano cost categories.

1. Approximately, 80% of users are willing to pay at least a 10% cost increase for a new feature or a

Table 9

Roles and Responsibilities

Project name: MSD purchasing process.

	Stakeholder			
Role	Responsibility	Signature	Date	Supervisor's Signature
Champion	Howard Gitlow	HG	9/1/2000	✓
Process owner	Dana Rasis	DR	9/1/2000	✓
Team leader	Bettina Arguelles	BA	9/2/2000	
Team member 1	Bryan Mercurio	BM	9/3/2000	
Team member 2	Jeremy Pressmen	JP	9/3/2000	
Finance rep	Lindsey Barton	LB	9/4/2000	✓
IT rep	Michelle Montano	MM	9/4/2000	✓

Suppliers	Inputs (Xs)	Process (Xs)	Outputs (Ys)	Customers
Ibix	Size	Insert flowchart of Purchasing Department on next page here	Durability	Workers of POI
Office Optimum	Ridges		Color	Managers of POI
	Vendor		Functionality	

Figure 3. The SIPOC analysis.

new product or service, above current offerings of products or services.

2. Approximately, 60% of users are willing to pay at least a 10% cost increase for a new feature or a new product or service, above current offerings of products or services.
3. Approximately, 10% of users are willing to pay a 10% cost increase for a new feature, or a new product or service, above current offerings of products or services.

The above questionnaire was given to the 100 paper shufflers in the PSD. Table 13 is used to classify the survey responses from each of the 100 paper shufflers for each of the CTQs into their Kano categories.

For example, if one of the paper shufflers answered the Kano survey about durability as is shown in Table 14, then the CTQ would be classified as "Attractive" for that paper shuffler, see Table 13 for classification table.

The responses for the 100 paper shufflers are tabulated in Table 15.

Durability is a must-be quality characteristic and its presence is required to achieve employee indifference. Its absence creates employee dissatisfaction. The PSD is not willing to pay more for durable MSDs. Functionality is a one-way quality characteristic. Its absence is related to employee dissatisfaction and its presence is related to employee satisfaction. The PSD is not willing to pay more for functional MSDs. Color is an indifferent quality characteristic. The PSD employees do not care about it and are not willing to pay more for MSDs that are uniform in color.

The final step of a Voice of the Customer analysis is to define each CTQ (see Table 16).

Returning to the first part of the define phase, team members can now define the project's objectives.

Project Objective 1: Decrease (direction) the percentage of MSDs that cannot withstand four or more bends without breaking (measure) bought by the Purchasing Department (process) to 00.62% (goal) by January 1, 2001 (deadline). Go for 4-sigma!

Project Objective 2: Decrease (direction) the percentage of boxes of MSDs with more than five broken clips (measure) bought by the Purchasing Department (process) to 00.62% (goal) by January 1, 2001 (deadline). Go for 4-sigma!

A correlation exists between the project objectives. A broken MSD cannot withstand four or more bends because it is already broken. Improving the percentage of functional MSDs per box will increase the percentage of MSDs that can withstand four or more bends.

MEASURE PHASE

The measure phase has three steps; they are: operationally define the CTQs, perform a Gauge R&R study on each CTQ, and develop a baseline for each CTQ.

Operationally Define the CTQs

First, team members operationally define durability and functionality by establishing criteria for durability and functionality, developing a test for each set of criteria, and formulating a decision rule for each criterion. The operational definitions for durability and functionality are shown below.

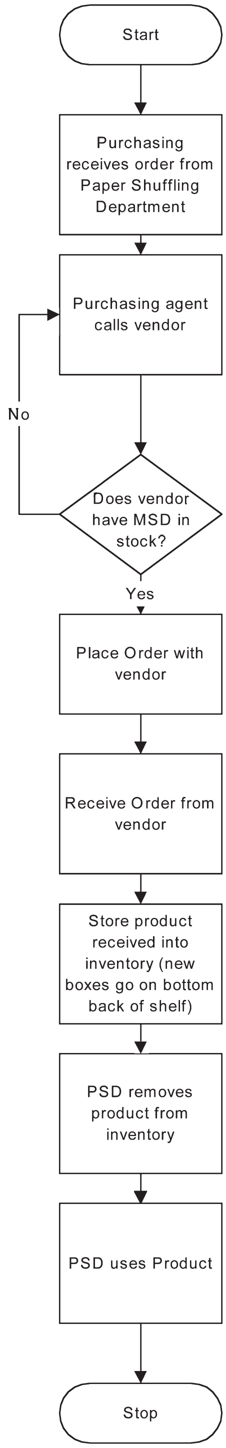

Figure 4. Purchasing flowchart.

Table 10

Voice of the Customer Questionnaire

Questions
What emotions come to mind when you think about MSDs?
What needs and wants come to mind when you think about MSDs?
What complaints or problems would you like to mention about MSDs?

Note: These questions do not consider the opinions, feelings, and attitudes of the upstream, downstream, and external customers of the PSD.

Operational Definition for Critical-to-Quality 1: Durability

Criteria for a selected MSD can be seen in Fig. 5.
Test for a selected MSD.

1. Select the "top-front" box of MSDs on the shelf in the inventory room.
2. Close your eyes, then open the box of MSDs, then haphazardly select one intact MSD. No switching is allowed.
3. Utilize the criteria for the selected MSD
4. Count the number of bends until breaking

Decision for a selected MSD
If the number of bends is ≥ 4, then MSD is conforming.
If the number of bends is < 4, then MSD is defective.

Operational Definition for CTQ 2: Functionality

Criteria for a box of MSDs:

Count the number of "broken" clips. A clip is broken if it is in two pieces, regardless of the relative sizes of the pieces. Clips can be broken only into two pieces.

Test for a box of MSDs:

Select the "top-front" box of MSDs on the shelf in the inventory room.
Count the number of broken clips.

Decision for a box of MSDs.

If the number of MSDs that are broken is ≤ 5, then the box of MSDs is conforming.

Table 11

Analysis Table for Voice of the Customer Data

1: Selected Market Segment	2: Raw "Voice of the Customer" Data	3: Affinity Diagram Theme (Focus Point)	4: Driving Issue (Cognitive Issue)	5: CTQ	6: Tech Specs
Paper organizing managers		Variation in durability **1**	Durability	Ability to withstand bending	$\geq$4 bends without breaking
	"My employees are frustrated about the MSDs. They complain that they break too fast." **1** and **2**	Variation in color **2**	Color	The number of different MSD colors	=1 color of MSDs
	"My employees are complaining that the MSDs are not holding up during the organizing process." **1**	Variation in functionality **3**	Functionality	The number of broken MSDs in a box	$\leq$5 broken MSDs in a box
	"The employees are also complaining that the color of the MSDs changes from one day to the next. It seems to be confusing them." **2**				
	"My employees are very unhappy with the purple and blue MSDs. They would prefer only one color of MSDs be used consistently." **2**				
	"My employees say that more than 5 MSDs per box arrive broken." **3**				
	"I've heard from numerous employees that the MSDs coming straight from inventory are already broken." **3**				
	⋮				
Hourly employees					
	"The MSDs are falling apart before we are ready to file the papers in to binders. An MSD should be able to take at least 4 bends." **1**				
	"The MSDs aren't helping us to do our work efficiently." **1** and **2**				
	"I would prefer if we only used one color of MSDs." **2**				
	"I don't understand why we use different colors of MSDs." **2**				
	"The MSDs just break when trying to bend them over the paper stacks. They should take at least 4 bends." **1**				
	"It is very frustrating when you open a brand new box of MSDs and find that more than 5 of the clips are already broken." **3**				
	"It is very time consuming to sift out the broken MSDs from a brand new box coming straight from inventory." **3**				

If the number of MSDs that are broken is >5, then the box of MSDs is defective.

The same box of MSDs is used for both operational definitions.

Perform a Gauge R&R Study on Each CTQ

Second, team members conduct an attribute Gauge R&R study on the measurement system of each CTQ to determine if it is adequate for the needs of the project. The measurement of durability requires a destructive test; hence, a simple Gauge R&R study was not done for durability at this time. In the near future, an operational definition of the testing process for durability will be established and testing will be audited to assure consistency. The measurement system for functionality is studied using the following sampling plan.

1. A shelf in the storage area contains boxes of MSDs purchased throughout the week. There are different types of MSD boxes in the storage area (different vendors, sizes, etc.).
2. The Gauge R&R study required 2 inspectors to sample the same 10 boxes of MSDs twice.
3. The top 10 boxes on the front of the shelf were selected for the Gauge R&R study.

Table 12

Kano Questionnaire for MSDs

CTQs	How Would you Feel if the Following CTQ Were *Present* in the Product?	How Would you Feel if the CTQ Were *Not Present* in the Product?	What Percentage Cost Increase, Over Current Costs, Would you be Willing to Pay for This CTQ? (%)
Ability to withstand ≥4 bends	Delighted [ ]	Delighted [ ]	0
	Expect it and like it [ ]	Expect it and like it [ ]	10
	No feeling [ ]	No feeling [ ]	20
	Live with it [ ]	Live with it [ ]	30
	Do not like it [ ]	Do not like it [ ]	40 or more
	Other [ ]	Other [ ]	
= One color of MSDs	Delighted [ ]	Delighted [ ]	0
	Expect it and like it [ ]	Expect it and like it [ ]	10
	No feeling [ ]	No feeling [ ]	20
	Live with it [ ]	Live with it [ ]	30
	Do not like it [ ]	Do not like it [ ]	40 or more
	Other [ ]	Other [ ]	
≤5 broken MSDs in a box	Delighted [ ]	Delighted [ ]	0
	Expect it and like it [ ]	Expect it and like it [ ]	10
	No feeling [ ]	No feeling [ ]	20
	Live with it [ ]	Live with it [ ]	30
	Do not like it [ ]	Do not like it [ ]	40 or more
	Other [ ]	Other [ ]	

4. The study is repeated as is deemed necessary by PSD management.

Two PSD managers have the responsibility of inspecting the MSDs for functionality; they are called Inspector 1 (Tom) and Inspector 2 (Jerry). Both Tom and Jerry counted the number of defective MSDs, twice, in random order. The functionality data are shown in Table 17, but not in random order.

A Gauge Run chart shows that there is no variation within inspectors or between inspectors, see Fig. 6. All the variation is between the 10 boxes of MSDs. Hence, the measurement system is acceptable to measure functionality.

Table 13

Classification Table for Responses to a Kano Questionnaire

Present Question Response (see column 2 in Table 12)	Not Present Question Response (see column 3 in Table 12): Delighted	Expect it and Like It	No Feeling	Live With It	Do Not Like It
Delighted	Q	A	A	A	O
Expect it and like it	R	I	I	I	M
No feeling	R	I	I	I	M
Live with it	R	I	I	I	M
Do not like it	R	R	R	R	Q

Table 14

Kano Questionnaire for MSDs

CTQs	How Would You Feel if the Following CTQ Were *Present* in the Product?	How Would You Feel if the CTQ Were *Not Present* in the Product?
Durability: Ability to withstand ≥ 4 bends	Delighted [X] Expect it and like it [ ] No feeling [ ] Live with it [ ] Do not like it [ ] Other [ ]	Delighted [ ] Expect it and like it [ ] No feeling [X] Live with it [ ] Do not like it [ ] Other [ ]

Table 15

Tabulated Responses to Kano Questionnaire

CTQs	Kano Quality Category	Kano Cost Category
Durability: ability to withstand 4 or more bends	$M = 80$, $O = 20$	0% = 100
Color: only 1 color per box	$M = 35$, $O = 15$, $I = 50$	0% = 100
Functionality: less than or equal to 5 broken MSDs in a box	$M = 10$, $O = 90$	0% = 100

Table 16

Definition of CTQs

CTQ	Definition of Unit	Definition of Opportunity for Defect	Definition of Defect	Kano Category
Durability: ability to withstand bending	MSD	MSD	Break < 4 bends	Must-Be: fundamental to the delivery of the most basic level of customer satisfaction
Color: number of different MSD colors	1 box of MSDs	MSD	MSD colors in one box > 1	Indifferent: far less critical than durability to paper shufflers
Functionality: number of broken MSDs in a box	1 box of MSDs	MSD	Broken MSDs in one box > 5	One-Way: improving the number of functional MSDs in a box will improve employee satisfaction in a linear fashion

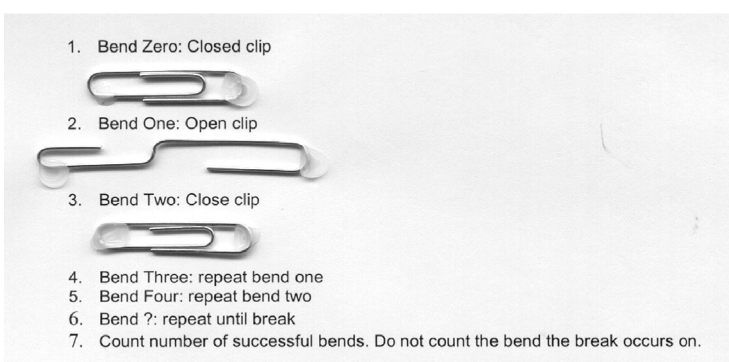

Figure 5. Criteria for number of bends of an MSD.

Table 17

Gauge R&R Data for Functionality

Box	Inspector	Count	Functionality
1	1	1	10
1	1	2	10
1	2	1	10
1	2	2	10
2	1	1	9
2	1	2	9
2	2	1	9
2	2	2	9
3	1	1	5
3	1	2	5
3	2	1	5
3	2	2	5
4	1	1	4
4	1	2	4
4	2	1	4
4	2	2	4
5	1	1	5
5	1	2	5
5	2	1	5
5	2	2	5
6	1	1	9
6	1	2	9
6	2	1	9
6	2	2	9
7	1	1	6
7	1	2	6
7	2	1	6
7	2	2	6
8	1	1	6
8	1	2	6
8	2	1	6
8	2	2	6
9	1	1	9
9	1	2	9
9	2	1	9
9	2	2	9
10	1	1	11
10	1	2	11
10	2	1	11
10	2	2	11

Develop a Baseline for Each CTQ

Third, team members conduct a study (as part of routine business) to determine the baseline capability for each CTQ. At the beginning of each hour, one box of MSDs is selected from the storage area. The procedure for selecting a box of MSDs is simply to select the topfront most box on the shelf. The selection process was not altered during a sampling period of two 8-hour shifts. Baseline capability data are shown in Table 18.

The yields for durability and functionality are both 0.375 as determined by the number of tests out of 16 trials shown in Table 18 that met their respective CTQs (i.e., at least 4 bends for durability, no more than 5 broken MSDs per box for functionality). This indicates very poor levels of durability and functionality for the MSDs received into the PSD and supports the initial yield estimates of 40.0, or 60% defective MSDs (see Table 4).

An individuals and moving range (I-MR) chart for the durability baseline data indicates that the variability of "durability" is not stable over time, see the bottom panel of Fig. 7. An investigation of the range between the eighth and ninth MSDs did not reveal any obvious special cause of variation that could be used to improve the durability of MSDs.

The I-MR chart assumes approximate normality of the CTQ (durability). The durability data are not normally distributed, see Fig. 8.

Hence, use of the durability I-MR chart is not advised at this time. However, the distribution of durability may approximate a Poisson distribution. Consequently, team members constructed a c-chart for the "count of bends" before each MSD breaks, see Fig. 9. (Note: If the "durability" was measured using a continuous measure-

Table 18

Baseline Capability Data

Hour	Durability	Functionality
Shift 1—Hour 1	5	12
Shift 1—Hour 2	7	4
Shift 1—Hour 3	3	8
Shift 1—Hour 4	2	6
Shift 1—Hour 5	9	1
Shift 1—Hour 6	2	5
Shift 1—Hour 7	1	11
Shift 1—Hour 8	1	9
Shift 2—Hour 1	12	6
Shift 2—Hour 2	9	6
Shift 2—Hour 3	3	9
Shift 2—Hour 4	1	5
Shift 2—Hour 5	1	4
Shift 2—Hour 6	1	5
Shift 2—Hour 7	1	9
Shift 2—Hour 8	4	10
Yield	$6/16 = 0.375$	$6/16 = 0.375$

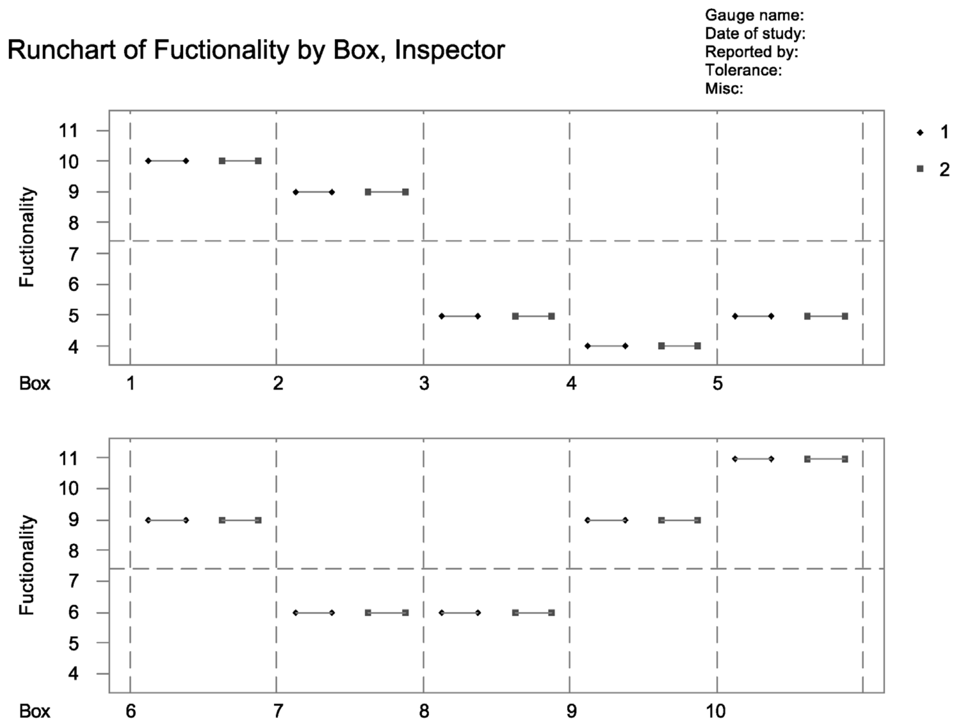

Figure 6. Gauge run chart for functionality (functionality is the number of defective MSDs in a box).

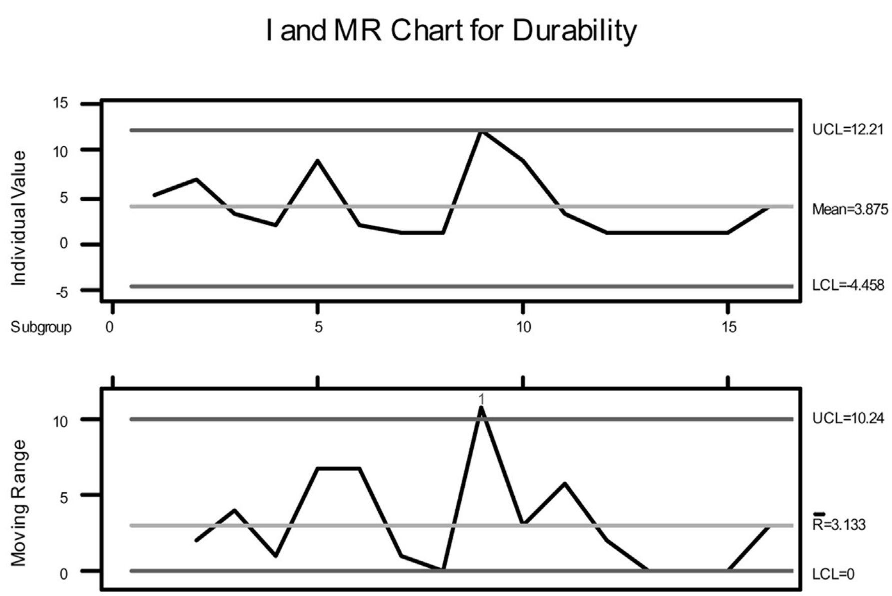

Figure 7. Individuals and moving range chart for baseline durability data.

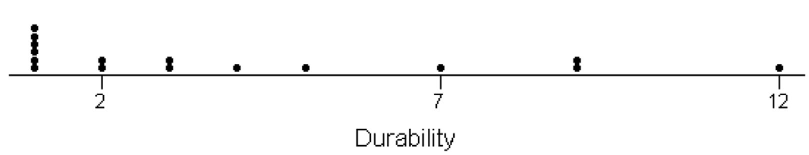

Figure 8. Dot plot of baseline durability data.

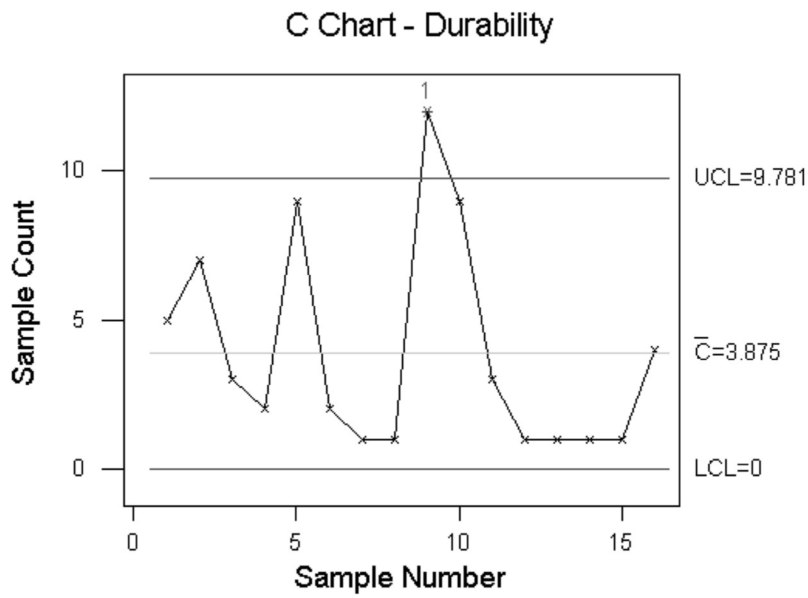

Figure 9. The c-chart for durability.

ment system allowing fractional number of bends before breaking, then a log or similar transformation of the distribution may be appropriate before using an Individuals-Moving Range charting procedure.). Figure 9 indicated a possible special cause during Shift 2—Hour 1 when 12 bends were observed for the durability test. Further investigation and notes related to the test did not reveal any obvious differences between the MSD tested and the others, although during the first hour the tester indicated that he may have bent the MSD slower than usual during the test which may have caused less stress and consequently more bends.

A c-chart for "functionality" (see Fig. 10) indicates that is stable over time.

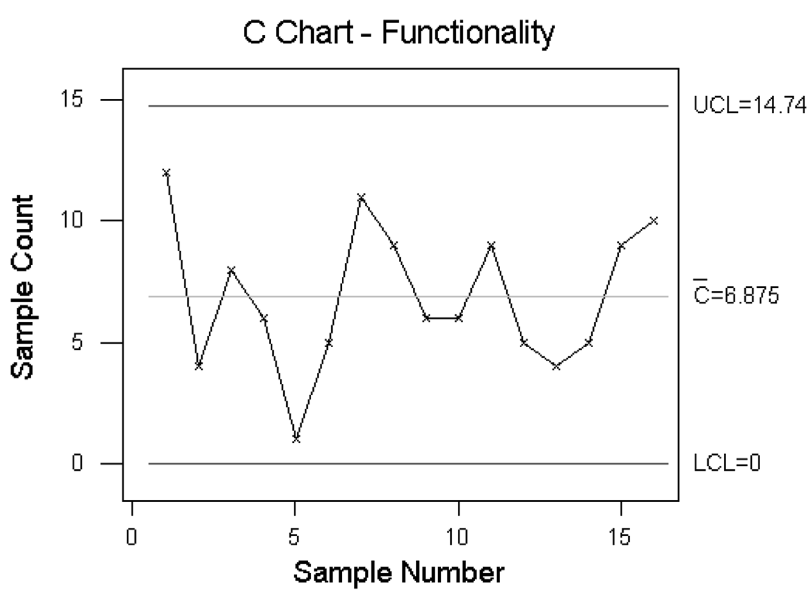

Figure 10. The c-chart for functionality baseline data.

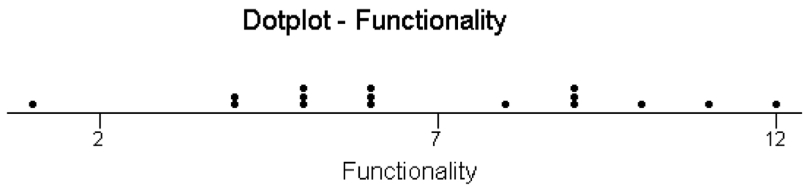

Figure 11. Dot plot for functionality baseline data.

Table 19

Current Process Performance for CTQs

	Yield		Defects Per Million Opportunities		Process Sigma	
CTQs	Current (%)	Desired (%)	Current	Desired	Current	Desired
Durability	37.50	99.38	625,000	6,210	~1.2	4.0
Functionality	37.50	99.38	625,000	6,210	~1.2	4.0

The functionality data appear to be approximately Poisson distributed (due to a Goodness of Fit test), see Fig. 11.

Hence, use of the functionality c-chart is acceptable at this time. Finally, team members estimated the current process performance for each CTQ in Table 19.

Notice the desired 100-fold improvement shown in the DPMO columns ($\text{Current} = 625,000$ and $\text{Desired} = 6,210$). This is consistent with the goals stated in question 5 of the Define Phase of the DMAIC model.

CONCLUSION

The Define Phase of the Six Sigma project has been completed. The business case has been clearly articulated, the SIPOC analysis has been completed, the "Voice of the Customer" has been collected and analyzed, and the initial project charter created by the Champion and Process Owner has been refined. Additionally, the Measure Phase has been completed. The CTQs have been operationally defined, Gauge R&R studies have been performed on the CTQs, and baseline data have been collected for the CTQs. This concludes the first part of a Six Sigma Green Belt project.

Those interested in a challenging learning experience may try to complete this case study on their own. The rest of the case study is presented in "POI: A Fictitious Six Sigma Green Belt Case Study—Part 2," which will appear in the next issue of *Quality Engineering*. That article will present the Analyze, Improve, and Control phases of the DMAIC method for this case study.

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