Chapter 5

Process Analysis and Organizational Metrics

5 Process Analysis and Organizational Metrics

Consideration of process and metrics are crucial in organizational restructuring since, firstly shorter process enhances speed and flexibility to the organization, secondly metric is an indicator which facilitates process improvement.

5.1 Process analysis

According to tester conversion trend in figure 4.2 and engineer time-spent analysis in figure 3.9, key processes under the organization responsibility that needed to focused are tester conversion (tester release), test related implementation, and yield analysis.

5.1.1 Tester Conversion (Tester Release)

This is one of the complicated processes demanding for multi-skill personnel to perform cross-functional work within the organization and throughout external organizations. Its process, figure 4.7 (a), can be simplified and shown in figure 5.1. After requirement plan is determined according to HGA build requirement, workflow of new tester setup or tester conversion exercises is begun. The flow can be divided into 2 major routs, primary route and rework route. Total hours of the process (conversion lead-time) can be simply calculated as follows:

$$T_T = T_{prime} + T_{rework} \qquad \text{(hours)}$$
$$T_{prime} = (I_1+T_s+I_2+T_c+T_o+T_f+T_i) \qquad \text{(hours)}$$
$$T_{rework} = (I_3+T_r+I_2+T_c)*(1-Y_a) \qquad \text{(hours)}$$

Where:
I_1 = average idle time per tester due to awaiting conversion
T_s = average time per tester for conversion
I_2 = average idle time per tester due to awaiting acceptance test
T_c = average time per tester for acceptance test
T_o = average time per tester for optimizing PRML channel
T_f = average time per tester for media factoring (calibration)
T_i = average time per tester for release and communication
I_3 = average idle time per tester due to awaiting rework
T_r = average time per tester due to rework exercises
Y_a = yield of acceptance test

Number of required tester in conversion each week can be calculated as follows:

$$N_{TC} = N_{TR}*T_T/24/7 \qquad \text{(systems)}$$

Where:
N_{TR} = number of testers requirement per week

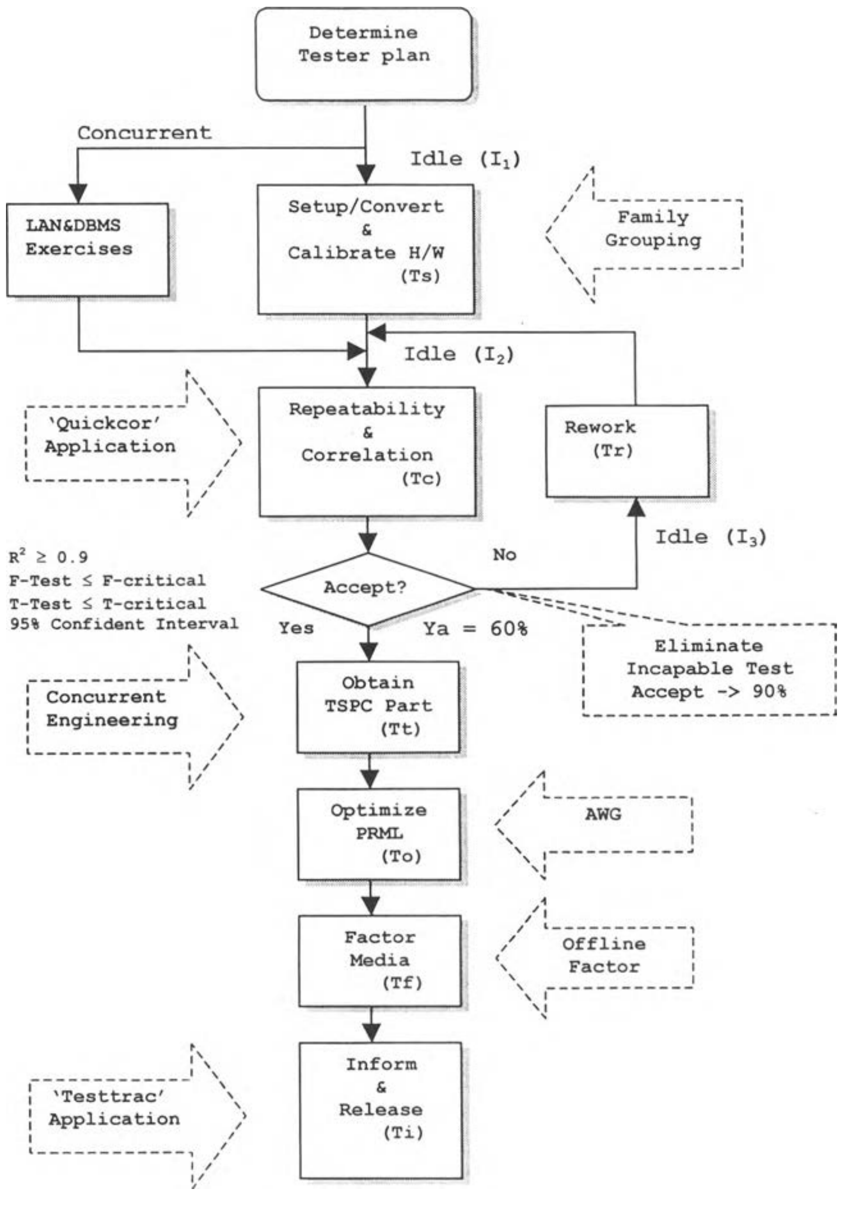

Figure 5.1 Simplified Tester Release Flow and Its Shortening Exercises

Testers are free-up from products that its requirement dropped each week. Usually the numbers of free-up testers are 2 times larger compared to the actual weekly required testers because of low acceptance test yield. This creates in-effectiveness in capital utilization.

Capital saving is directly relate to number of testers required, $75,000 USD each. Broken arrows in figure 5.1 are activities introduced to shorten tasks.

5.1.2 Test Related Implementation

Every new development has to be qualified prior to implementing in manufacturing to minimize unexpected impact due to changes. Workflow in figure 4.7(b) can be simplified and shown in figure 5.2.

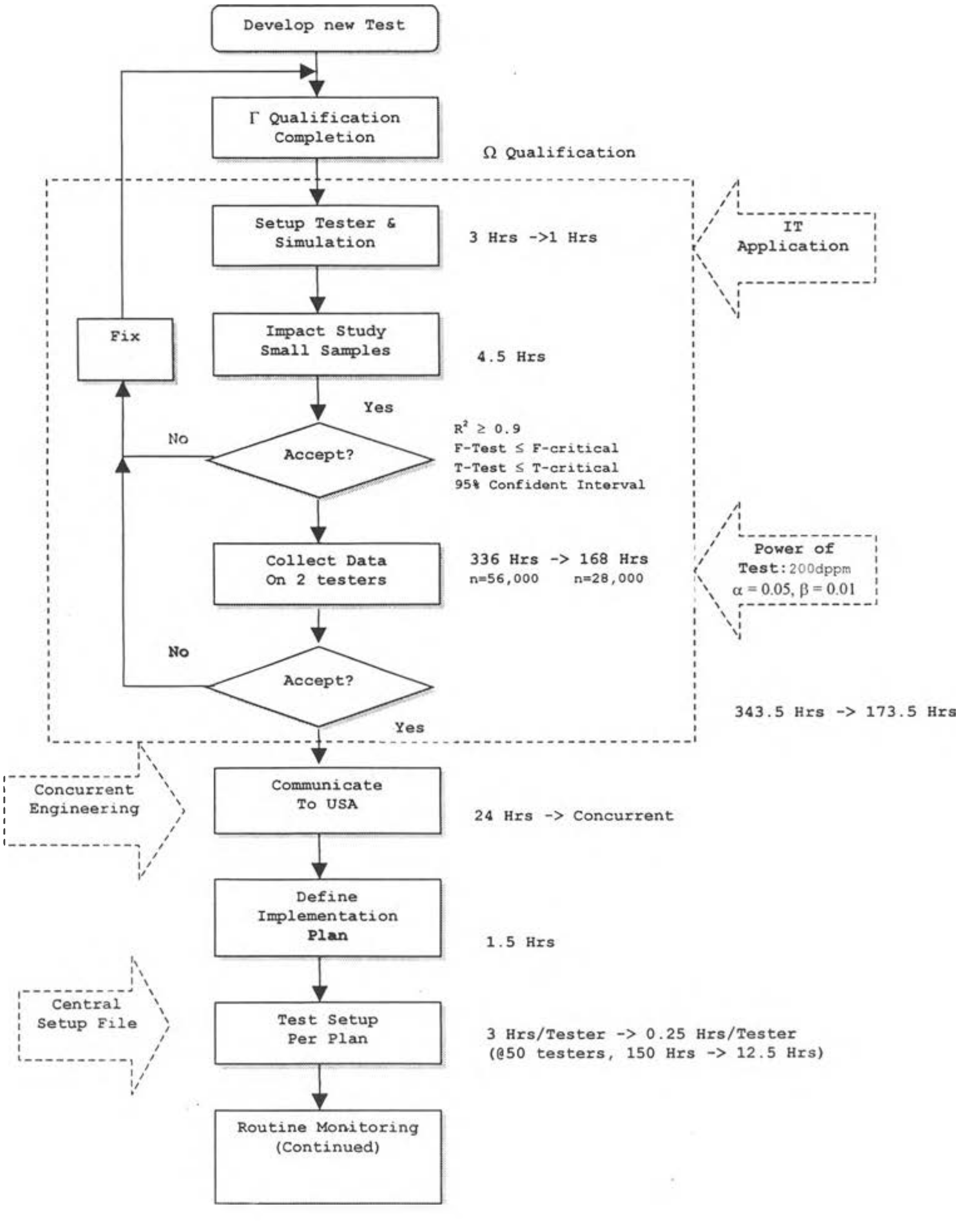

Figure 5.2 Simplified Test Implementation Flow and Its Shortening Exercises

After Gamma (Γ) qualification of over 100,000-lines code and over 2,000 combination of several different dimensions, the change will be qualified for an Omega (Ω) level which is in manufacturing environment. The process typically takes 519 hrs on fifty-tester product. The major time consuming is in data collection for anomaly analysis. Two testers are enabled to manufacturing for 336-hrs worth of data, approximately 56,000 samples. The sample size seems to be too large; a proper sample size need to be determined statistically based on power of test approach.

At probability of type-I error (α) = 0.05 and type-II error (β) = 0.01, a sample size of 27,063 is sufficient to detect 200 dppm different with the following hypothesis:

$$H_o: P = P_o$$
$$H_1: P > P_1$$

Considered 0.002 the alternated proportion and 0.000 the hypothesize proportion.

(The alternated proportion is not the value of alternated hypothesis, but the value at which power is wanted to evaluate.)

This can reduce 336 hrs data collection down to 168 hrs, 28,000 samples.

The second major is on "test setup per plan", employee has to do manual operation to make change at each individual tester which is not practical for large multiple-tester products. With a central file approach, every tester is linked and updated its software setup from central file via network. At 50-tester product, 150-hrs exercise can be reduced to 12.5 hrs.

Concurrent engineering approach can be used in oversea communication task where other activities can be continued in parallel. Overall process can be reduced from 519 to 187.5 hrs, 64% improved.

5.1.3 Yield Analysis

Yield analysis workflow shown in figure 4.7 (c) is most likely involved with data query to vies in different dimensions and to investigate the change of key input variables which are very complicated for current process and product sensitivity. The analysis structure are divided into 2 primary levels with multiple sub-levels as follows:

1. External Contribution (upstream processes)
   - 1.1 Wafer Fabrication
     - 1.1.1 Static electrical impacts
     - 1.1.2 Dynamic electrical impacts

1.2 Slider Machining
1.2.1 Mechanical impacts
1.2.2 Electrical impacts
2. Internal Combination (HGA manufacturing)
2.1 Material Loading Control
2.1.1 Hi-end portion
2.1.2 Low-end portion
2.2 In-process Control
2.2.1 Mechanical impacts
2.2.2 Electrical impacts
2.2.3 Operator dependant
2.3 Tester
2.3.1 Hardware
2.3.2 Software
2.4 Tester Associates
2.4.1 Test media
2.4.2 PRML channel optimization
2.4.3 Media factoring parts
2.5 Environment
2.5.1 Power line noise
2.5.2 Vibration
2.5.3 Particles

Yield analysis improvement is highly depend on skill and knowledge-base of engineer incorporated with tools. An idea to create a center of excellence and standard analysis flow to improve analytical skill and systematic approach is valid. IT tools can be incorporated to maximize speed and capability of analysis which is exhibited in chapter 6 "IT applications to support restructuring".

5.2 Organizational Measures

The importance of measurement is that the performance measures have to be aligned to corporate objectives and to what customer wants. Schonberger (1996), mentioned in his principle 11; "You get what you measure".

Measures of the organization, which is a support organization to manufacturing, have to reflect operational objective measures, i.e. operating cost per unit, scrap cost per unit, schedule adherence, DPPM at customer incoming, indirect to direct labor ratio, and inventory turn-over.

Teparuk is a cost-center involving with several aspects of quality as well as high flexibility of changeover in mass volume production to support product's time-to-market. Four major aspects in this organization definitely will have to support the operational metrics:

5.2.1 Cost Aspect

It is a must for the organization to understand cost related factors contributed by the organization both directly and indirectly.
Out of operating cost per unit, 10% is due to tester depreciation, 5.5% is due to test engineering support i.e. equipment supplies; indirect labor support; and other fringe expenses, and 3.3% is due to test operator and space utilities. Thus, the major links to operating cost are number of tester, which can be describes as a cascaded structure below with its variables:

- Contribution to cost per HGA (18.8%)
  - Tester Depreciation (10%)
    ~ Test capacity(which determine Number of testers)
    ~ Tester cost
  - Tester supplies (3%)
    ~ Number of testers
    ~ Parts usage
    ~ Parts cost
  - Indirect labor (2.5%)
    ~ Number of testers
    ~ Number of exercises
    ~ Exchange rate
  - Test operator (2%)
    ~ Number of testers
    ~ Exchange rate
  - Space utilities (1.3%)
    ~ Number of testers
    ~ Tester size
    ~ Exchange rate

It is clearly seen that "Number of testers" is the major variable that plays significant role in the 18.8% of HGA product cost since it is a one-to-one variable to "Tester depreciation", "Test operator", and "Space utilities". Test engineering can indirectly contribute to that. Cost of tester supplies and indirect labor supporting testers are the area that the organization is directly responsible for.

Thus organization focus has to be on activities that increase tester capacity/utilization to reduce number of testers, tester supplies, and indirect labor management. Objective goals setting has to include improvements of test time or test UPH (units per hour) and test yield.

5.2.2 Quality Aspect

There are several measures, which are performed by Quality organization but some other specific test quality need to be measured by Test Engineering organization.

Tester variation is the key measure for test equipment after all the testers have passed statistical acceptance test and released into manufacturing. It is very important to measure tester variation and put a proper control to the tester to be virtually real-time since they are dynamic tester and sensitive to changes in the process. Key measures of the tester quality are:

Tester Statistical Process Control (TSPC): It is a statistical approach to regularly monitor tester performance over time on all key test parameters. This control is designed for detecting a step function shift in tester baseline. When several hundreds of test system are being controlled, overall quality of tester is monitored by tester variation, z-score technique can be useful.

Z-score: It is another statistical approach to measure deviation of average value of individual tester compare to standard deviation of others. Test data of each tester, around 500 systems with half a million records a day, are collected via the organization's local area network (EIS's LAN). The data is then converted to database format then automated applications, which is developed in-house, regularly query and process to engineering and statistical report format. With this approach, test engineering can identify potential problem testers by taking a further analysis and technical actions to the outliners.

Note: $\boxed{\text{Z-score} = (x_i - \bar{x})/\sigma}$ for each tester

Where x_bar = average parametric value of all testers
x_i = average parametric value of specific tester
σ = parametric standard deviation of all testers

Z-score-Out (%): The measure is a number of z-score-out events occurred, compare to possible events. For example, a total of 100 testers on one product taking measurement of 20 parameters: a total possible event is 2000. If there are 10 testers have z-score of 20 parameters beyond ±2, the percentage of z-score out is 10*20/2000 = 10%. It is not necessarily that all parameters cause impact. Typically, the focus is on top 6 defects accounting for more than 85% contribution.

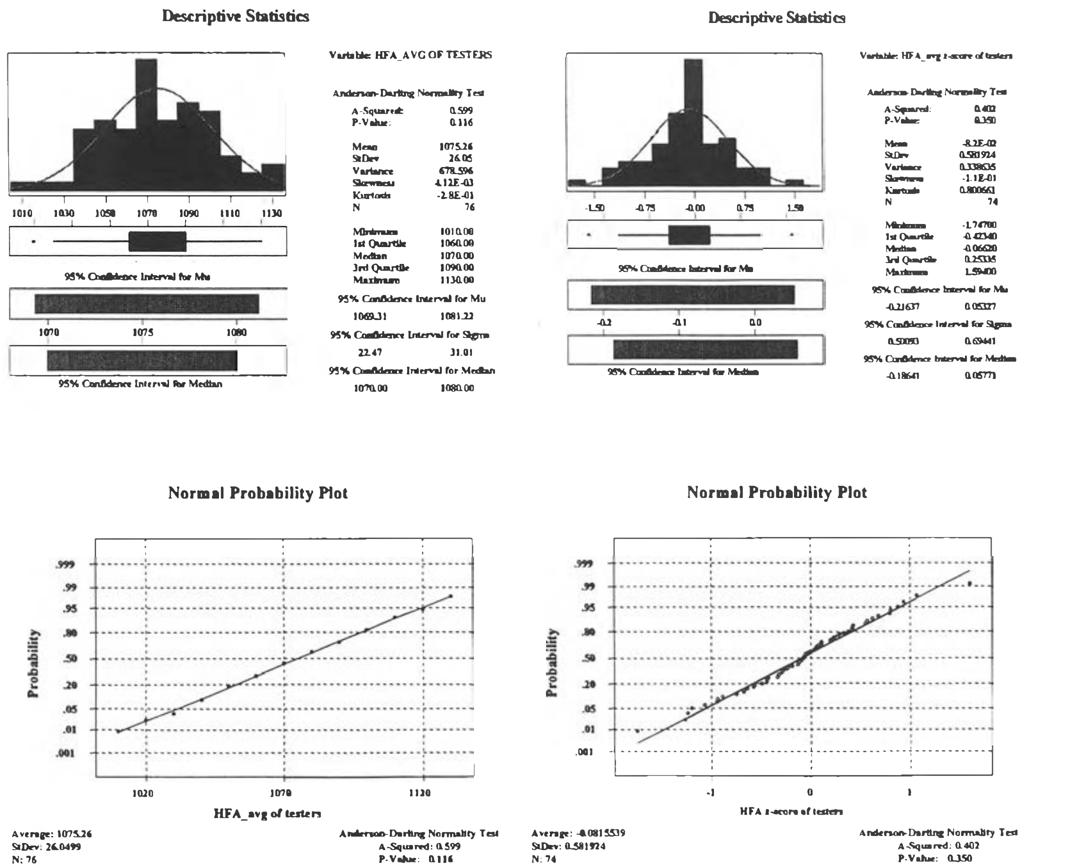

Figure 5.3 Distribution and Normal Test of Average HFA Measurement of Each Tester and Its Z-score (total of 78 testers)

The reason of using z-score was that, user can put all 20+ parameters in one z-score chart no matter what unit of measuring they are, as long as they are normal distribution. Figure 5.3 and 5.4 demonstrates parametric distribution vs. z-score distribution and their normal test of 2 selected parameters out of over 20 parameters. It is clearly seen that these 2 different units of measurement and range, μV vs. μ″ and 1000-1200μV vs. 10-25μ″ respectively, can be normalized in z-score format to seek for an outliner of $\pm3\sigma$.

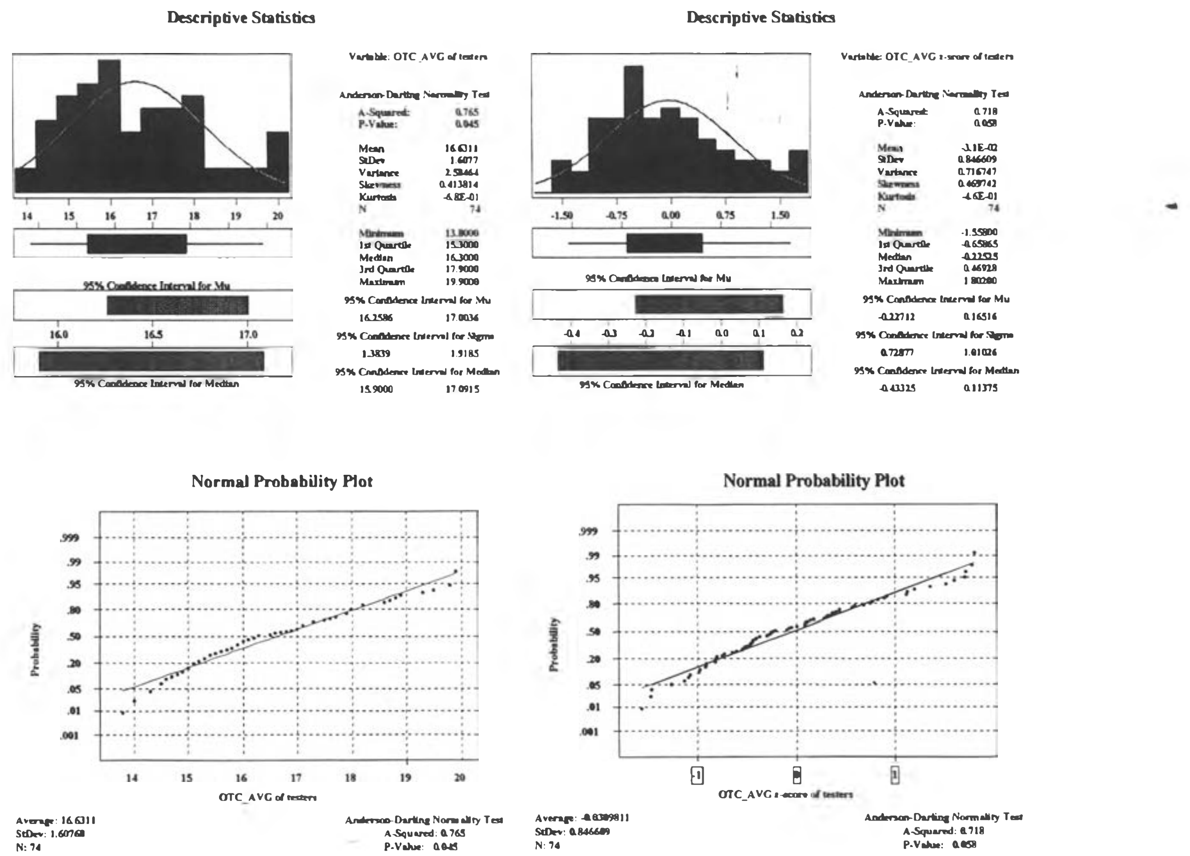

Figure 5.4 Distribution and Normal Test of Average OTC Measurement of Each Tester and Its Z-score (total of 78 testers)

Impact due to Implementation Error ($): Human creates error as well as changes. Thought error can hardly prevent in a certain environment, but impact due to the error can be minimized. It is somewhat related to speed of reaction to the error prior to disaster due to consequences of that error. Manufacturing impact due to test related implementation is calculated into dollars associated due to containment cost, re-screening cost, handling cost, scrap cost, and any other cost that impact to downstream process.

5.2.3 Speed Aspect

Tester conversion lead-time: It is measured in hours according to 5.1.1. This is one of the key elements to support flexible manufacturing, but does Teparuk really need to bring it down to 24 hrs or below?

Real-time abnormal tester monitoring: There are several factors contributing opportunity lost in test process where product is incapable (test yield is at 60-80%), and test process is very sensitive. Abnormal yield is another measure to trigger a potential problem in the shop floor. To handle today's quality related to test process issues, a 24 hours data report for engineering analysis is inadequate and could not deliver proper actions in timely basis.

There are several type of tester anomalies which could be a step function, degradation, or random events. System and tools are in place for detecting step function but there is no effective system in place to detect some certain level of degradation and random events due to small magnitude of high frequency noise and vibration. Tools need to be developed to detect such events in timely basis such as micro defect on test media during test. Several techniques have been deployed in the past several years, from Signal Modulation to Acoustic Emission Sensor. Now a day, micro defect became smaller and measured around 20-50 μ" wide, a more effective technique is being developed in TTD's lab. While the development is in process, a system that used for real time monitoring can be deployed to minimize opportunity loss due to slow reaction.

Measuring number of testers that have 2 or 3 hrs consecutive abnormal yield, beyond $\pm 1\sigma$ of instantaneous product average yield, against total possible events will be used to measure relative speed of effective reaction. This measuring technique allows system to provide an indicator with a relevant to speed of reaction combined with quality of the reaction.

The reason for not being lower than 2 hrs is wafer (material) yield variation, which could cause instantaneous poor yield tester without actual tester issue, and finally lead to over-reaction at tester. Current contribution due to wafer variation is over 40% probability, and other techniques for real-time effective detecting need to be developed in parallel.

5.2.4 Flexibility Aspect

It is very important in world class manufacturing to be flexible in mass volume production to changeover from one product to another according to customer requirement, which is more and more fluctuate every year. It is highly required in Lean Manufacturing which moves toward demand-pull concept. Tester conversion is a good indicator to measure flexibility in this organization. Number of conversion exercises are increased with the rate of 208 exercises per year during 1993-1997, the rate will be increased to 600 exercises per year in 1998 as shown in figure 4.2.

Flexibility is, in most case, highly related to speed and capability. It can be earned by improving capability and speed of the resources. Driving for flexibility without building capability to resource will affect organization in the long run, where higher degree of flexibility is required while it is too late to know that the organization has insufficient capability to response.

Number of tester testers per employee and number of tester conversions per employee will be a metric to measure flexibility of organization.

5.2.5 Customer Satisfaction Aspect

One of the most important factors in running a business is customer satisfaction. Knowing who are direct and indirect customers, knowing what they need and want, and knowing what their perception is, then the improvement can be made toward the right direction. Sometimes customer perception is not a real physical quality issue, but it is more likely an issue of communication or awareness of our customer.

Customer Satisfaction Index (CSI) is developed to measure key subjective aspects to organization Soletron's CSI form has been modified to be a 5 levels of scoring assessment in 6 different aspects from TE's customers as shown in figure 5.5.

The assessment form has been initially distributed via electronics mail to make customers think freely on their aspects and collected it as a baseline prior to face-to-face discussion with them.

From: Roong Sivaratana

To: Boonyong Danthainam@Seagate, Sirichai Sukhumanant@SEAGATE, Jakree Pandhumsoporn@SEAGATE, Montri Laohaphan@SEAGATE, Panupant Viroonhamas@SEAGATE, Asichart Vatanotai, Chittiporn Puprichitkul@SEAGATE, Sirirat Euaypadung@SEAGATE, Peerapol Wilaiwongstien@SEAGATE, Visut Sorndetthongkum@SEAGATE, Karn Osathanondh@Seagate

cc: Somying Sukseeree@SEAGATE, Supar Phokachaipat@SEAGATE, Visan Palattanavit@SEAGATE, Surasith Phuphaisan@SEAGATE, Palapetch NaSongkhla@SEAGATE, Kirk A Roby, Wantanee Vongthai@SEAGATE, Madan M Misra, Brent Bargmann, Pom Piemsomboon

Document Link Information:

Document: Test Eng Appraisal

TE is a multi-function organization with multiple customers who have different requirements and priorities, herebelow is an attempt to make another step of organizational improvement.

Please see Test Engineering Customer-Focused Structure and their mission/responsibility by opening the attached .ppt file in the doclink. Please notify the organization that you are a direct customer from .ppt file and appraise that organization with 5 level scoring. You may be a customer of more than one organization, please do it seperately and return mail to my secretary, Kamolrat Ba.
Please encourage your managers to spend their 15 minutes to help us deliver the quality support.

The appraisal topics are wide-open as you can freely think of any aspects and put it into your comments in order to improve TE organization.
(Please use red color for your marks and comments)

Appraised Organization: ( )TTC, ( )TCS, ( )TTS, ( )TTD, ( )TTI, ( )EIS

	1	2	3	4	5
	Poor	**Need Improvement**	**Meet Requirement**	**Exceed Requirement**	**Exceptional**
Co-operation					
Quality					
Technical supports					
Communication					
Flexibility					
? specify					
Overall					

Comments:

You may open the document by clicking on this link.

Figure 5.5 Test Engineering's CSI Assessment Form, Distributed via Electronic Mail

5.3 Organization Metrics

Metric is an indicator or measure which facilitates process improvement. According to previous discussion, metrics for test engineering organization can be determined as shown in table 5.1.

Table 5.1 Test Engineering Organizational Metrics

Aspects	Before	Target	Comments
Quality			
Z-score Out (%)	32.3%	0	Focused group TTC + IT
Annual $Impact, Implements	114k	0	Focused group TTI
Speed			
≥3 hrs Abnormal Tester (%)	1.16%	0	Focused groups + IT
Abnormal Tester React (hrs)	7-14	0.25	IT leverage
Conversion Lead-time (hrs)	310	24	Focused group + IT (Target 62)
Flexibility			
Annual Conversions per H/C	2.5	4	End 1996 vs. Early 1998
Testers per H/C	1.5	3	End 1996 vs. Early 1998
Actions taken per day	<100	N/A	IT leverage
Customer Satisfaction Index			
Co-operation	3.0	>4	Customer-focused alignment
Quality	2.6	>4	Customer-focused alignment
Technical Support	2.8	>4	Customer-focused alignment
Communication	2.6	>4	Customer-focused alignment
Flexibility	2.6	>4	Customer-focused alignment
Overall	2.7	>4	Customer-focused alignment
Cost per HGA			
Equipment Supplies ($)	0.02	0.02	Maintained, more activities
Indirect Labor ($)	0.02	0.02	Maintained, more activities