Lecture No. 14: Quality and Its Control (2)

1. Concept of Quality Control
2. Inspection and “Building Quality Into Product”
3. Design of Inspection Process
4. Concept and Practice of TQC

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Recognized Quality and Profitability (PIMS data)

Hypothesis:

high quality $\rightarrow$

high share + high price $\rightarrow$

low relative cost $\rightarrow$

high profitability

Reference: PIMS Principle
1. Concept of Quality Control

History of quality control

Statistical Quality Control (SQC)
--- established along with a mass production structure in USA in 20th century

1924: Control chart by Schewhart with Bell Research Center

1940 – 1950: Development of SQC in USA

Post War: quality control seminars (CCS) by GHQ (Japan visits and coaching by Deming and Juran)

1960s: TQC in Japan, technique’s ramification and refinement in US companies
Quality Control is:

- **Total quality control** ・・・ ”TQC”

- **Design quality control** ・・・ product development per se

- **Conformance quality control**
  ・・・ being ”quality control” normally at job site
  conformance quality control at total-company level
  being called TQC (T・QC)

or, ”CWQC” (Company-Wide Quality Control)
Control • PDCA Cycle (Plan–Do–Check–Action)

1 Plan
2 Do
3 Check
4 Action
2. Inspection and "Building Quality Into Product"

Step by step, trace back to the source point of "design information flow" to prevent defects.

(1) no inspection
(2) shipping inspection
(3) receiving inspection/in-process inspection
(4) feedback of defect information, and improvement
(5) one-by-one production
(6) self inspection
(7) prevention of defect
(8) product design resistant to noises
Inspection and Quality Building

1  No Inspection

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p267 figure.7.9)
2 Shipment inspection

Product Design
(Info. M+A+B)

Equipment/Worker
Info. Stock B

Equipment/Worker
Info. Stock A

M+A+B

M+A+B

M+A+B

M+A

M+A

M

Material inventory

Goods in process stock

The first work

The second work

Final product stock

Scrap and adjustment, etc.

Customer

Info. M+A+B

yes

no

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p267 figure.7.9)
3. Receiving Inspection/In-process Inspection

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Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (P267 figure 7.9)
Inspection and Quality Building

4 Feedback and Quality Improvement

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (1 p268 figure.7.9)
6 Voluntary inspection

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p268 figure.7.9)
7 Defective prevention

Customer

■ Scrap and adjustment, etc.

Equipment/Worker Improvement

■ Prevention of defective generation

Equipment maintenance
Standard work thoroughness
Education and training

Product Design

(Info M+A+B)

■ Equipment/Worker Improvement

Equipment maintenance
Standard work thoroughness
Education and training

Flow of information
Flow of thing
Work (processing thing)

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p269 figure.7.9)
8 Product design strong in the noise

Product design that weaves manufacturing and reliability

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Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p269 figure 7.9)
3. Design of Inspection Process

**Inspection** = to judge each item by good or failure, by comparing results of testing in some way, against a **quality judgment criteria**

or, to judge each **lot** by qualified or disqualified comparing against a **lot judgment criteria**
Classification by Inspection Target

(1) Receiving inspection — purchased material, parts
(2) In-process inspection — in-process products
(3) Shipping inspection — finished product

(a) Individual-unit inspection
(b) Lot-unit inspection (inspection of samples only)
Classification by Measured Data for Inspection

(1) **Counting inspection**
    ---- discretely judge product by good or bad

(2) **Metric inspection**
    ---- measure product attribute as continuous quantity
    measure defect rate by its distribution and tolerance

Classification by way of handling defects
    scrap, recycle, re-work (amend), other
Classification by Frequency/Density of Inspection

(1) Total inspection

(2) Inspection of first and last samples of a lot

(3) Random inspection (counting model)

   Extract $n$ units from lot (N).
   When the number of defects exceeds a qualification judgment criteria,
   that entire lot is judged disqualified,
   and when the same number is below the same criteria,
   the whole lot is judged qualified.

(4) Inspection by control chart (metric extraction inspection)

   Control chart = to differentiate a trouble cause from an accidental cause
   Focus on improving the former
Method of Counting Extraction Inspection

Lot N

real defect ratio \( p \)

real good product

\( N - pN \)

real defect product \( pN \)

random sampling

measured
good product

measured
defect product \( x \)

measured
good product

\( n - x \)
Example of x-R Control Chart (filling quantity of powder: in unit of gram)

Author making (reference: Yozo Mukawa 'Quality Control for Cotowaricou Student and Engineer')
Reference: Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p275)
Example of x-R Control Chart

**x-R control chart**

PC second machine
rubber plate #500

Sample size = 5

Average

Range

Lot number

UCL = 5.248
CL = 5.021
LCL = 4.794
UCL = 0.83
CL = 0.395

(mm)
### x-R Control Chart — Data Sheet

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**Average:** $\bar{x} = 5.021$, $R = 0.395$

**Sampling of 5 units**
**Inspection Design and Quality Cost**

**No inspection**  
--- zero inspection cost. cost corresponding to defects, only.

**Extraction inspection**  
--- extraction inspection cost + cost of defects accrued from a lot qualified in inspection + cost of total inspection of a lot disqualified by inspection

**Total inspection**  
--- cost of total inspection, only. zero cost corresponding to defects.

"defect rate = unit inspection cost / unit defect cost"  
at break even

1. no inspection  
   \[ C = N \cdot p \cdot F \]

2. extraction inspection  
   \[ C = n \cdot I + g (N - n) \cdot p \cdot F + (1 - g) (N - n) \cdot I \]

3. total inspection  
   \[ C = N \cdot I \]

break even point for 2 and 3:  
\[ p = \frac{I}{F} \]
Inspection Method and Quality Cost

Note: Assuming rework cost at zero

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 ( p277 figure.7.11)
Design of Extraction Inspection

To review on a diagram the relationship between a real defect rate \((p)\) and a lot’s pass rate.

(1) **AQL (Acceptable Quality Level)**:
   Reason on a maker’s side insisting, “The lot is of low defect rate, and shouldn’t be mistaken as disqualified.” (5% as standard)

(2) **Producer’s risk**:
   No matter how high a reject rate of AQL-level lot is, it’s better not to go beyond this level. (5% as standard)

(3) **LTPD (Lot Tolerance Percent Defective)**:
   To pass a lot whose defect rate exceeds this criteria is not acceptable from a consumer standpoint.

(4) **Consumer risk**:
   Probability for a LTPD-level lot to be mistakenly qualified should be below this.
Design of Extraction Inspection

Desirable lot pass rate to producer

Desirable lot pass rate to consumer

Producer’s risk and consumer’s risk

Set c and n

OC curve

Choose n and c to settle OC curve like this

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 ( p278 figure.7.12)
Operating Characteristic Curve (OC Curve)

When real defect rate extracts $n$ unit from universe $p$,

probability $Pr(x)$ at which $x$ unit of defect is mixed follows binomial distribution.

When a rule is to pass a lot having number of defects below $c$ unit,

pass rate $= Pr(x \leq c)$ can be expressed in cumulative probability of binomial distribution.

This pass rate curve (cumulative probability of binomial distribution) is "OC curve".

When $n$ and $c$ are set, so is a shape of OC curve.

Conversely, when AQL, LTPD, producer's risk, and consumer's risk are determined,

OC curve to pass 2 points [(AQL, producer's risk) and (LTPD, consumer's risk)],

and corresponding $n$ and $c$ are determined.
Sample Size (n) and Shape of OC Curve

pass rate of lot (p)

reject rate of lot

defect rate of lot (%)

n = 30
n = 50
n = 100

α

β

注：母集団（N）は1000、c=3を仮定している。
4. Concept and Practice of TQC

(1) **Traditional SQC** ———
To emphasize optimization of inspection design
(assuming certain level of defect rate)

control chart, extraction inspection, test plan, etc.

(2) **Production thought like JIT/TQ** ——— Improvement of process capability

To emphasize “building quality into product”, “in-process total inspection”

(1) not to accrue a defect in the first place

(2) no to accrue a defect outside of the station

(3) to grasp defect outside of the station as early as possible

(4) to find and improve a basic cause of the defect swiftly
TQC (Total Company Quality Control)

TQC in Japan is CWQC (Company-Wide Quality Control)

Conceptually started in USA (Feigenbaum and others) → expanded in Japan

Its characteristics ----

- **Total company** activity (all layers, all departments)
- **Continuous** improvement (problem solving)
- **Small group activity** (QC circle)
- Usage of **statistical method** at job site ("QC 7 tools", etc.)
- emphasis on **education/training**
- Cross-company **popular organization**
  (Union of Japanese Scientists and Engineers, Japan Management Association, Japanese Standards Association, Japan Productivity Center)
QC Circle

Kind of Small Group Activity

“Small group to voluntarily run a quality control activity in the same work office”

Many groups being composed of approximately 10 persons.

To meet a few times a month by selecting a leader.

To execute continuous improvements, all participation, by using QC method,

Presentation activity, recognition system.
QC Story

Periodical problem-solving steps (routine)

- theme
- reason for taking up a particular theme
- grasping status quo
- factor analysis
- measure
- confirmation of effectiveness
- brake (maintaining performance, relapse prevention)
- issues left to be addressed and way to proceed further (follow-up)

Same for MAIC method of "Six Sigma" (measure-analyze-improve-control)
QC 7 Tools

pareto chart, characteristic diagram (fishbone diagram), histogram, check sheet, control chart, scatter graph, by layer

Its features --

(1) **simple** and easy to understand

(2) **graphic** (control by eye sight)

(3) **problem solving/improvement oriented**

Tools for statistical analysis should not be a monopoly of experts. **Use at the job site.**
Numerical Example: Defect Accruals and Cumulative Rate (Pareto Chart)

Over size in hole dimension is the largest problem.

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p287 table.7.1a figure7.14a)
Numerical Example: Distribution of Measured Value (Histogram)

--- Exceeding Tolerance Over

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p288 figure.7.14c)
Numerical Example: x−R Control Chart  ---- No Problem

注: 基本的なデータと管理限界の計算根拠は以下の通り。

観測1回当たりのサンプル数(n)=5
観測回数10 回
サンプルの平均 x の平均(x)=10.23
範囲(R)の平均(R)=0.6
以上から推定される母集団の標準偏差=0.6 ÷ 2.326=0.26
これに対応する x の上方管理限界=x=10.23 + 0.6 x 0.577 = 10.58
これに対応する x の下方管理限界=x=10.23 - 0.6 x 0.577 = 9.88
範囲(R)の上方管理限界=0.6 x 2.115=1.27
係数(2.326, 0.577, 2.115)は、管理図用係数表の「n=5」の欄から引用した。

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 ( I p289 figure.7.14d)
Numerical Example (by Layer): Distribution of Measured Value (Y company’s steel sheet)  --- Y company’s product is OK.

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 ( I p290 figure.7.14e)
Numerical Example (by Layer): Distribution of Measured Value (Y company’s steel sheet) --- X company’s product is the problem.

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p290 figure.7.14f)
Numerical Example: Factor Analysis on Lack of Precision in Hole Diameter (Characteristic Diagram)

- work condition
  - fluctuation of electric current
  - fluctuation of ガス流量
  - relative angel of work and torch
  - relative distance of work and torch
  - work position fix

- machine
  - machine rattle
  - abrasion of torch's tip
  - dispersion of material quality
  - dispersion of thick plate
  - material

lack of precision in hole diameter

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p291 figure.7.14g)
Numerical Example: Torch Distance and Bore Diameter Dimension (Scatter Graph)

--- Certainly related

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p291 figure:7.14h)
Policy Control

Kind of **Objective Control**

- company motto → basic policy → long-term policy → annual policy
  
  total company annual policy by top management
  (objective and measure)

  → expansion by **top-down** onto each division/department/individual
  (policy expansion)

  → discussion between superior and subordinate
  rotate **PDCA cycle** (TQC method)
Policy Expansion

expansion of quality policy
division policy
quality policy
procurement policy
cost policy
quality assurance division policy
quality control department policy
factory policy
policy of other functions
policy of other departments
policy of other departments
policy of other departments

Note: Boxes in gray indicate policies related to quality.

Source: X Company

Takahiro Fujimoto
'Introduction to Production Management'
Nihon Keizai Shimbun, Inc. 2001 (p295 figure 7.15)
Role of Quality Assurance Division

① Previously, a quality assurance division executed inspections.

↓

② Now, a quality assurance division emphasizes functions of planning, operation, and organizer relative to total company quality assurance activities.
Problems of TQC

Self-righteous activities to win Deming Prize (totalism, spirit doctrine)

Losing substance

Negative effect of top-down method
From TQC to TQM (1996)

Effect of **TQM (Total Quality Management)** started in USA

In reference to “**Malcom Bordeaux ridge national quality prize**”

Emphasis on **customer satisfaction/total quality**

View of “**quality of management**”

Directly related to **management strategy**

Enriching **problem-solving methods** (Six Sigma’ MAIC method)

**Broadened** problem solving activities
ISO 9000 Series (9001, 9002, 9003)  
= ISO (International Organization for Standardization;  
an international standard established by a worldwide  
federation of each national standard bodies in 1987

Standards regarding to “quality system” which customers demand to supplier of a particular product

“Quality system” : documentation of steps for a series of activities, and recording of these activities’ results, for suppliers to assure the quality of own company’s products. Third-party screening/registration organizations implement screening/authorization on behalf of customers.

A system strongly reflecting Western thoughts of a contract society.

To Japanese companies of TQC model, this has not provided much effectiveness in enhancing their direct competitiveness.

Some appraise an effectiveness of basic motions’ confirmation.

However, it is perhaps unlikely that this system will play a major role in advancing quality.