Goal for the Course

The principal goal of this course is to provide you with an understanding of tools and techniques for improving the profitability and competitiveness of your company.

Books and Reprints

- Notes and reprints supplied
- Reading list provides supplementary references.
- Books -- optional

Class Format

- Outline
- Lecture and Discussion.
- Summary by Participants
- My Summary -- and comparison with points intended to make.
- Discussion throughout

Exams and Grading
Why Quality

- U.S., the biggest economic force in the world
  - U.S. GNP more than twice that of Japan
  - 2 times the size of combined GNP of France, Germany, and England

- Why then
  - We continue to lose market share
  - Why we keep laying off people
Concerns about American Manufacturing

- American industry continues to decline in world markets
- Trade deficit
  - More than 3M jobs lost due to trade imbalance in the 80's
  - From biggest creditor to biggest debtor nation in the world
  - More than 2% of GNP spent in annual debt service
- No great sustainable advantage in high tech or service sector
  - Trade deficit in high technology and in financial, insurance, communication, travel and cargo, etc.
- 25% of Americans and more than 50% of Japanese and Europeans believe that US industries cannot deliver quality products
Other Danger Signs

- 4 times as many indirect employees and twice the direct employees in U.S. as in Japan for the same output. 10 times more assembly repair and 16 times more warranty costs

- Japanese unit labor cost has decreased by 9% since 1975. While U.S. labor has increased by 60% since 1975

- Rate of new product introduction in Japan is 22 times greater than United States

- Quality Perceptions
  - 25% of Americans and more than 50% of Europeans and Japanese believe that U.S. industries cannot be relied on to deliver quality products.
What is Common in all these Industries

<table>
<thead>
<tr>
<th>Automobiles</th>
<th>Food Processors</th>
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<tbody>
<tr>
<td>Cameras</td>
<td>Microwave Ovens</td>
</tr>
<tr>
<td>Stereo Components</td>
<td>Athletic Equipment</td>
</tr>
<tr>
<td>Medical Equipment</td>
<td>Computer Chips</td>
</tr>
<tr>
<td>Color Television Sets</td>
<td>Industrial Robots</td>
</tr>
<tr>
<td>Hand Tools</td>
<td>Electron Microscopes</td>
</tr>
<tr>
<td>Radial Tires</td>
<td>Machine Tools</td>
</tr>
<tr>
<td>Electric Motors</td>
<td></td>
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</tbody>
</table>
Loss of Market Share

- During the last 25 years, the U.S. has lost 50 to 90% of world market share in 20 major industries including steel, automotive, consumer electronics, machine tools, textiles, semiconductors, nuclear power, construction equipment, and medical equipment.

- Since mid-1985, nearly 50% of Fortune 500 companies have gone bankrupt. Result is 2.9 million jobs eliminated.
United States Trade Balance
<table>
<thead>
<tr>
<th></th>
<th>1960</th>
<th>1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>3%</td>
<td>17%</td>
</tr>
<tr>
<td>USA</td>
<td>34%</td>
<td>20%</td>
</tr>
</tbody>
</table>
Loss of Leadership

- 1985 wages
  - U.S. $12.82
  - Japanese $6.45
  - Germany $9.60

- In 1993 Japanese and German wages are higher than U.S. wages

- Wages are not the issue in foreigners' cost position, productivity is
How Can We Compete

MIT commission on industrial productivity cites four options in "Made in America" book

- Place tariffs, quotas on all imported goods
- Recession in U.S. to slow down the demand of foreign expensive goods
- Devalue our currency

Since 1985 the dollar has been depreciating

1985 \(293Y = 1\$\)
1990 \(130Y = 1\$\)
1993 \(100Y = 1\$\)

- Improve the quality of our products and services

In the first 3 options, the cure is worse than the disease.
The Dollars Descent Against the Yen
Why Industrial Companies Lose Customers

Handling Complaints Effectively Converts Dissatisfied Customers into Loyal Customers

Satya Sharma
Performance VS TQM

- Japanese companies using TQM bring new products to market twice as fast as U.S. companies, have less than half as many defects, have 3 times higher productivity

- Companies who have won Deming Prizes in Japan report superior performance in every category than non-prize winning companies
History of Quality

- Prior to World War II
  - Quality meant variation in desired physical characteristics of the product (product based approach)
  - Conformance to specifications (Manufacturing based approach)

- Several individuals before and after the war played key roles in the use of quality as a management system
Historical Perspective

- After W.W.II, U.S. was the dominant economy in the world
  - Hugh war capability converted to consumer goods manufacturing
  - High awareness of quality
- Countries devastated by war
  - No infrastructure left
  - Designed more efficient and flexible
- American managers thought they were invincible
  - Management systems became obsolete
  - Quality started suffering
  - Outflow of U.S. money overseas
  - Reversal of roles
Common Teachings

- Continuous Improvement
- Remove Unwanted Variation
- Improve Processes
- Customer Satisfaction
Total Quality Management System

- Quality is determined by senior managers because they
  - control resources
  - control market entry decision
  - decide management system

- Based on customer focus, total improvement and respect for people, continuous improvement, and fact based decision making

- Supporting elements
  - leadership, education and training, communication, reward and recognition, and measurement
The American Manufacturing Enterprise

THE WORLD

THE FIRM

Financials

Quality & Time

Design

Production

COMPETITORS

CULTURE

Environment

Legal & Regulatory

METHODS

Communications

CUSTOMERS

Suppliers

Satya Sharma

Slide 26
"Not only the wealth; but the independence and security of our country appear to be materially connected with the prosperity of its manufacturers. Every nation, with a view to those great objectives ought to that end possess within itself all the essentials of national supply. These comprise the means of subsistence, habitation, clothing and defense".

Alexander Hamilton

December 5, 1791
Some Things We Should Believe

- Manufacturing is the basic source of wealth and in turn, of societal well being.

- Control of R&D is essential to maintaining a strong competitive manufacturing base.

- Conversely, manufacturing supports and nurtures a healthy R&D community -- separate manufacturing and R&D and both lose.

- Product and process cannot be separated.
What is Competitiveness?

"The degree to which a nation, under free and fair market conditions, produces goods and services that meet the test of international markets while simultaneously maintaining and expanding the real income of its citizens."

President's Commission on Industrial Competitiveness, Global Competition: the New Reality (Government Printing Office Washington, D.C.), vol 2
## Antiquated Images Hide Manufacturing's New Look

<table>
<thead>
<tr>
<th>MYTH</th>
<th>REALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>We're in a post-industrial society</td>
<td>In the 1980s and so far in the 1990s, U.S. manufacturing's direct share of the economy has remained stable at more than a fifth of the gross domestic product. In addition, nearly half of total economic activity depends at least indirectly on manufacturing.</td>
</tr>
<tr>
<td>U.S. manufacturing is not globally competitive</td>
<td>U.S. exports doubled between 1986 and 1992 and continue to set records. A large trade surplus with Europe and a rebounding surplus with Mexico and other countries show U.S. products can penetrate the entire spectrum of world markets.</td>
</tr>
<tr>
<td>Manufacturing is plagued by low productivity</td>
<td>Average productivity growth in manufacturing has been approximately 3% a year for 12 years, compared with the national average, which remained close to zero until last year.</td>
</tr>
<tr>
<td>Manufacturing is low-tech</td>
<td>Nearly three-quarters of research and development spending in the U.S. is performed by manufacturers. Manufacturing is the main source of advances in technology and innovation.</td>
</tr>
<tr>
<td>High prices? Poor quality?</td>
<td>Recent surveys show American manufactured goods today offer greater value and higher quality than at any time in three decades.</td>
</tr>
<tr>
<td>Manufacturing jobs aren't as good as other jobs</td>
<td>Manufacturing workers receive 15% higher compensation; 98% receive company-paid health benefits; manufacturers spend more than $30 billion a year on education and training.</td>
</tr>
</tbody>
</table>
Manufacturing Creates National Wealth

- Manufacturing creates national wealth by adding value to raw materials through the application of people skills, investment in tools, energy and technology. Manufacturing's economic pump, when it can generate productivity growth, delivers a far larger percentage of added value to the economy than any other single sector.

- Manufacturing is the primary source -- supplying more than 80% -- of merchandise export earnings, which directly increase economic growth and jobs. In addition, close to half of services' export earnings consist of royalties and fees directly linked to manufacturing.

- Manufacturing directly through new production and indirectly through its purchase of services supports the bulk of U.S. economic activity.

- The U.S. manufacturing base consists of approximately 362,000 establishments of which 5,500 employ 500 persons or more. About 65% of these firms, around 234,000, employ 19 or fewer people.
What is Productivity?

Officially the U. S. Government Bureau of Labor Statistics defines productivity for various industry groups as follows:

"The output per labor hour or dollar of wages"

This old definition is inappropriate and inadequate for almost all kinds of manufacturing operations because product costs are no longer dominated by labor costs. Better measures are needed and are available but are not generated or tracked for the U.S. as a whole.

We will study new methods that are appropriate for today's environment.
MANUFACTURING MATTERS

The notions of "A Post-Industrial Society" and of "A Service Economy" are simply wrong.

To maintain and improve the U.S. standard of living we have no choice but to keep manufacturing here because it generates the "good" service jobs.

A permanently falling dollar translates into continually impoverishing America.

The only route is to improve productivity and hence competitiveness through every means at our disposal.

Fortunately there are good new tools at hand and preliminary results of their application are encouraging.

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Early Leaders of Manufacturing Innovation

- W. A. Shewhart
- B. Small
- J. Juran
- W. E. Deming
- F. Taylor
- F. & L. Gilbreath
- H. Ford
<table>
<thead>
<tr>
<th>Relative Market Share</th>
<th>60%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Low</td>
<td>27</td>
<td>20</td>
</tr>
</tbody>
</table>

**Relative Perceived Quality**

- Superior: 38
- 67%: 29
- 33%: 20
- Inferior: 7

From: Buzzell, R. and Gale, B.
The PIMS Principles
Chapter 6.
### III. Quality & Time

#### How Quality Affects Price

<table>
<thead>
<tr>
<th>Relative Market Share</th>
<th>Relative Perceived Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>inferior 33%</td>
</tr>
<tr>
<td></td>
<td>superior 67%</td>
</tr>
<tr>
<td>Relative</td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>102</td>
</tr>
<tr>
<td>25%</td>
<td>101</td>
</tr>
<tr>
<td>low</td>
<td>101</td>
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<tr>
<td></td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>107</td>
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<td></td>
<td>108</td>
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</tbody>
</table>

III. Quality & Time

Two Routes to Improved Profitability Through Quality

Through Market Gains

- Improved Performance, Features, Reliability
  - Improved Reputation for Quality
    - Increased Market Share
      - Experience-based Scale Economies
        - Increased Profits
        - Higher Prices

Through Cost Savings

- Improved Reliability or Conformance
  - Increased Productivity
    - Lower Manufacturing Costs
      - Increased Profits
    - Lower Rework and Scrap Costs
      - Lower Service Costs
    - Lower Warranty and Product Liability Costs

These routes are not exclusive.

from: David A. Garvin, What Does "Product Quality" Really Mean? The Sloan Management Review (Fall 1984) p. 25
III. Quality & Time

Two Routes to Improved Profitability Through Cycle Time

Through Market Gains
- Reduced Cycle Time and Cycle Time Variance
  - Earlier into the market
  - Increased Project Profit
    - Increased Market Share
      - Experience-based Scale Economies
        - Higher Prices
          - Increased Profits

Through Cost Savings
- Reduced Cycle Time and Cycle Time Variance
  - Reduced Inventory WIP ~ Cycle Time
  - Reduced Days Outstanding
    - Increased Cash
      - Reduced Carrying Charges
      - More accurate forecasts
        - Lower Component Costs
          - Increased Profits
III. Quality & Time

Conclusions & Recommendations from David Garvin's Study of U.S. and Japanese Air-Conditioner Manufacturers. -1

- In weaker U.S. firms management emphasized meeting production schedules much more strongly than meeting quality objectives.
- 2 of 3 weaker U.S. firms paid worker’s on total output rather than defect free output.
- to achieve consistent improvement a formal system of goal setting is required.
- specificity in goal setting is necessary to success.
- specific data on defects -- code and product associated must be available -- in many U.S. companies it was not available.
- Japanese firms insist on extreme precision in reporting.
- High quality has a strong inverse correlation with design changes.
  --the better U.S. plants had fewer design changes.
  the use of less experienced workers.
- Japanese firms used extensive reliability engineering -- much greater than U.S. firms.
- Japanese firms made extensive use of SQC.
Conclusions & Recommendations
from David Garvin's Study of U.S. and Japanese
Air-Conditioner Manufacturers. -2

- Japanese firms used more inspection than U.S. but used it
differently -- inspector's goal is production stability.
- Japanese firms did extensive training of new workers -- 6 months.
  and workers become adept at tracking down problems.
- Japanese firms had little bumping -- a more stable work force.
- One or more persons had explicit responsibility for dealing with vendor's.

The Japanese advantage in production came less from revolutionary technology than from close attention to basic skills and to the reduction of all unwanted variations in the manufacturing process."
Time and Trust

Time to complete any task depends is inversely proportionational to trust:
Consider:

- JIT lines and JIT suppliers
- International relations
- The adversarial relationship in government contracting.
- Law suits
Quality Drivers -- Example
Quality Requirements in Assembly Manufacturing
Problem Statement

n parts are to be assembled onto a circuit board or into a motorcycle.

find the level of quality of the individual parts and assembly operations must be achieved to assure that the yield of boards or bikes is a specified value.

assume initially that all parts and operations have the same quality.

generalize to parts with varying ppm defective levels

The problem translates into calculating the probability that the completed board shall have no bad component.
Quality Drivers -- Example

Quality Requirements in Assembly Manufacturing

Solution

what is the probability of drawing \( n \) green balls (good) from an urn that contains a large number of green and red balls where the fraction of good balls is \( r \). say \( r = .9 \).

assume independent probabilities so the probability of drawing a green ball is constant at .9. Consider filling two places -- two draws. The probability of

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<tbody>
<tr>
<td>green</td>
<td>green</td>
<td>probability</td>
<td>.81</td>
</tr>
<tr>
<td>.9</td>
<td>.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>green</td>
<td>red</td>
<td></td>
<td>.09</td>
</tr>
<tr>
<td>.9</td>
<td>.1</td>
<td></td>
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<td>red</td>
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<td>red</td>
<td>red</td>
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<td>.01</td>
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<tr>
<td>.1</td>
<td>.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sum of all probabilities</td>
<td>1.00</td>
</tr>
</tbody>
</table>

note that sum of all probabilities adds to 1.0 as it must.
III. Quality & Time

Quality Drivers -- Example
Quality Requirements in Assembly Manufacturing
solution continued

Generalizing to the case of n components where:
q ≡ quality of each individual component components
Y ≡ yield of an assembly of n components
Y = q₁ × q₂ × q₃ × q₄ × .... qₙ = qⁿ

Now we want to do the inverse problem:
find q to get a specified system yield Y.

\[ \ln Y = n \ln q \]
\[ \exp(\ln q) = q = \exp\left(\frac{\ln Y}{n}\right) \]

example: for assembly yield of 99% and 100 components we find:
q = .999899

or the fraction defective is 1 - .999899 = .000101
or
101 parts per million (ppm) defective.
Component and Process Quality Required to attain specified yield of assembled product

Region Suitable for JIT/TQC Manufacture

- yield = 0.5
- yield = 0.9
- yield = 0.99
- yield = 0.995
III. Quality & Time

Calculating Yield in the High Quality region

We have noted that for n components where:

\( q \equiv \text{quality of each individual component component} \)

\( Y \equiv \text{yield of an assembly of } n \text{ components} \)

\[ Y = q_1 \times q_2 \times q_3 \times q_4 \times \ldots \times q_n = q^n \]

For the case of parts and operations

where the quality level is high -- a few ppm

the calculation can be simplified.

if we let

\[ q = 1 - \frac{\text{ppm}}{10^6} = 1 - \delta \]

then:

\[ Y = (1 - \delta_1) \times (1 - \delta_2) \times (1 - \delta_3) \times \ldots \times (1 - \delta_n) \]

and since \( \delta_1 \times \delta_2 \) is very small

\[ Y = 1 - \delta_1 - \delta_2 - \delta_3 \ldots = 1 - \frac{1}{10^6} \sum \text{ppm} \]