Lancaster University
Management School

Introduction to Operations Management

Quality Management

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Quality management

Controlling variation and meeting expectation

1. The essential problem of quality
2. Process capability
3. Control charts
4. Total quality management (TQM)

Quality Management

Part 1: The essential problem of quality

Controlling variation and meeting expectation

Variation as the essential problem of quality

- Quality is not *ad hoc*
- Usually defined as the difference between an ideal, and an actual situation (ASQ)
- An ideal situation represents a *standard* – can be defined differently by customers, internal processes, suppliers, society, and shareholders
- Though companies strive for this standard, it is usually not achieved, or at least not achieved fully to everyone's satisfaction
- Variation – change in data, expected outcomes, or *quality*, as defined and *agreed as a standard* by stakeholders
- Planned changes, executed well, lead to product improvements and efficient processes
- Unplanned changes are almost always bad – and costly

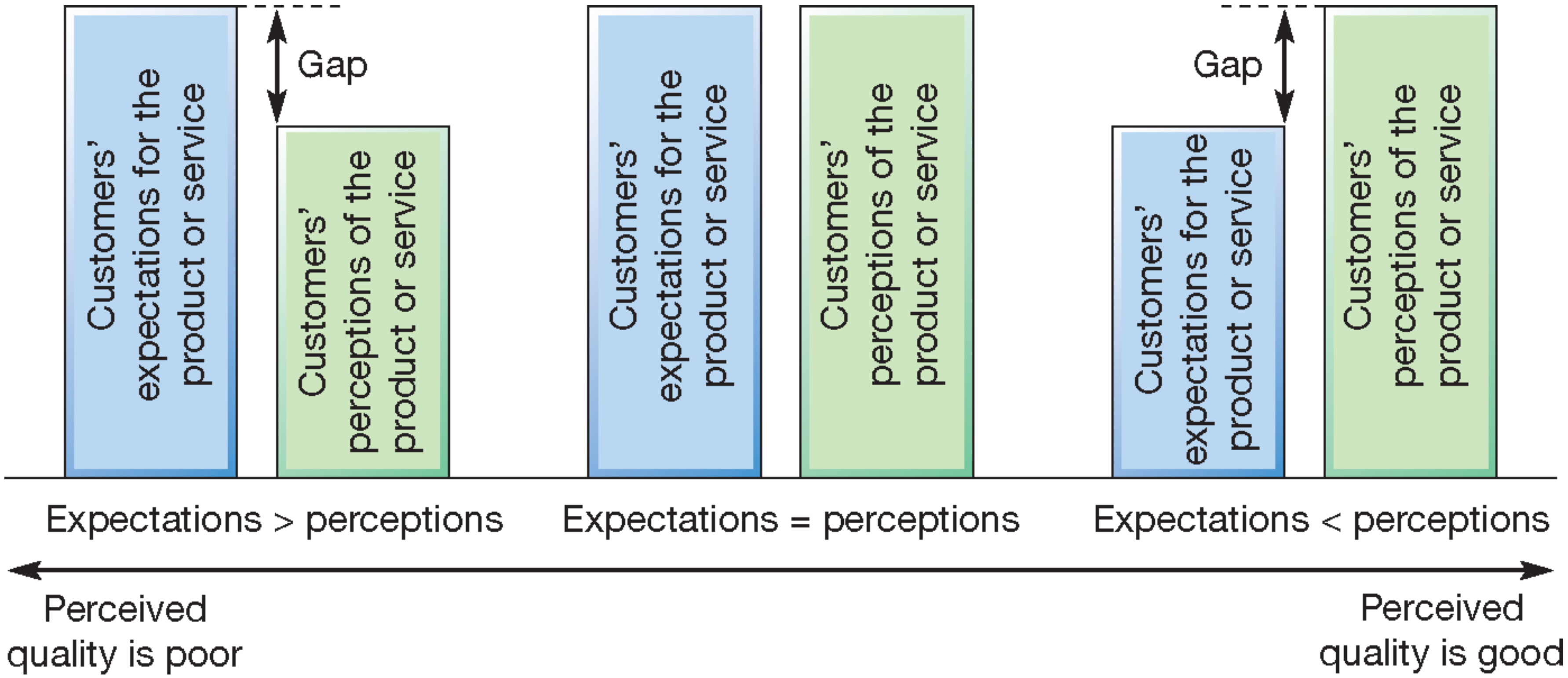
Variation as the essential problem of quality

- *Quality management* involves identifying and managing *variability* in a *product or process*
- Some variation is intentional e.g. varying service levels depending on demand or customer needs
- Unplanned variation:
  a. Common causes – inherent in a system (degradation, drift, random variation)
  b. Special causes – non-random causes (arise due to some special circumstances)
  c. Tampering – action taken to control variation (sometimes leading to more variation)
  d. Structural variation – no two items are ever exactly same

Variation as the essential problem of quality

- Controlling variation
  - Variation from specification undermine a products' or services' function
  - Aggregated data over long periods obscures variation
- Meeting expectation
  - Customers', clients' and users' view of what makes quality should be decisive
  - Even though there is usually a lot of information asymmetry with producers

Perceived quality is governed by the magnitude and direction of the gap between customers’ expectations and their perceptions of the service or product



The essential problem of quality

- Customer expectation – operation’s specification gap
  - E.g. expectations of durability vs durability specification
- Concept – quality specifications gap
  - E.g. expectations of sustainability vs actual specification
- Quality specification – actual quality gap
  - E.g. size vs actual size
- Actual quality – communicated quality gap
  - E.g. Communicated speed of network vs actual speed
- *Variation in all of above*

Systems for controlling variation

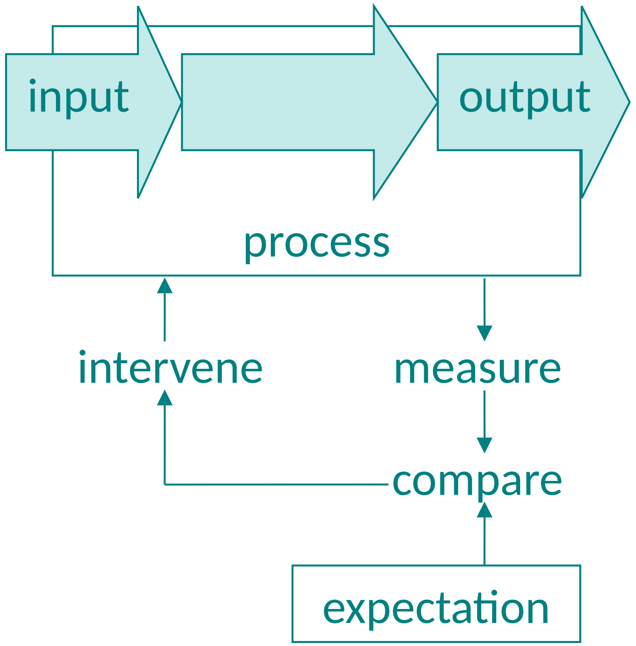
- The following systems are variation-controlling:
  - Any room thermostat temperature mechanism
  - Vasodilation / vasoconstriction processes in animal bodies
  - A phone / laptop that brightens the screen automatically in low light

- Identify which of the following they have in common:
  A. A barrier stopping external changes reaching the system
  B. A mechanism of detecting changes and offsetting them
  C. A process of predicting changes and counteracting them
  D. These are all different processes and clearly have nothing in common

Controlling quality: a basic model

Operations systems that turn variable inputs into constant outcomes…
…are ‘homeostatic’

- They sense or measure an outcome
- Then they compare this with some prior expectation or set point
- Then act to correct the discrepancy



Controlling quality: what to measure

The first step in designing such a system is identifying what to measure, i.e. reducing 'quality' to specific characteristics

- E.g. characteristics for product (car) & service (flight)

Quality Characteristic	*Car*	*Flight*
• functionality	speed, road-holding…	duration, facilities…
• reliability	mean time to failure…	keeping to the published flight times …
• durability	useful life…	competitiveness
• recovery	ease of repair…	resolution of failure…
• appearance	styling, finish…	cleanliness, décor…
• contact	sales staff demeanour	airline staff demeanour…

Controlling quality: what to measure

Step two is reducing characteristics to specific measures

- ‘Variables’ are continuous quantities – e.g. a length or weight
- ‘Attributes’ are discontinuous – e.g. a configuration being correct or incorrect

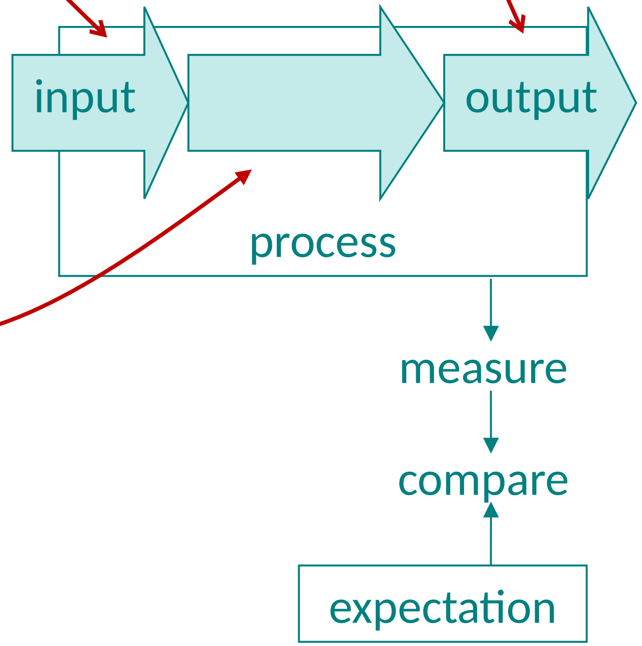
Quality Characteristic	*Variable* (quantitative)	*Attribute* (qualitative)
• functionality	test bed measurements?	ride quality ok?
• reliability	average time to failure?	reliability satisfactory?
• durability	life before scrapping?	life as predicted?
• recovery	time to repair?	serviceability acceptable?
• contact	level of help?	feel well served?
• appearance	blemish count?	colour to specification?

Controlling quality: when to measure

Step three is deciding when to measure a quality characteristic

- ***Before*** (e.g. measuring materials coming into an operation) removes deviation earliest
- ***After*** (e.g. measuring products or services leaving the operation) offers maximal ***assurance***
- But measuring **during** its processes maximises ***control***

- Usually the last (i.e. during) is preferred
- So quality control is **process** control
  - Rather than input control or output control
  - Although these may also be needed



Controlling quality: how much to measure

- The final step is deciding how much to measure
- Measuring all products or services sounds like the most secure, but
  - All may be destructive and costly (some quality tests are destructive tests)
  - And it doesn't guarantee quality as tests have imperfect reliability e.g. tester / conditions unreliability
- So it's normal to sample
  - But samples can be unrepresentative
  - So some statistical analysis is needed

- Hence quality control is statistical process control (SPC)

Controlling quality: SPC

There are 2 main elements of Statistical Process Control (SPC):

- The first is removing enough variation to meet functional need
  - By plotting variation in the measure during a period on a distribution e.g. 100 units of a first batch of production, time taken to service 10 customers in a queue
  - Applying *tolerance limits* expressing functional need for that process e.g. the amount of paracetamol in a 500mg tablet must be between 450mg and 550mg
  - Adjusting the process until this distribution fits between these limits

Controlling quality: SPC

There are 2 main elements of Statistical Process Control (SPC):

- The second is ensuring variation is *not reintroduced* in the process
  - By charting variation over time as operation continues
  - Applying *control limits* defining boundaries beyond which we know the process has changed
  - Testing observations against the limits

Systems for controlling variatio

- This is analogous to the problem of target sports:
  - Achieving a sufficient standard
  - Watching each shot for significant discrepancy
- Achieving a sufficient standard
  - Getting close: needing skill, practice, right equipment
  - Getting centred on the target: adjusting sights, calibrating judgment

- Watching each shot for significant discrepancy
  - From fatigue or loss of concentration by the performer
  - Or from equipment failure or sight movement

Quality Management

Controlling variation and meeting expectation

Part 2: Process capability

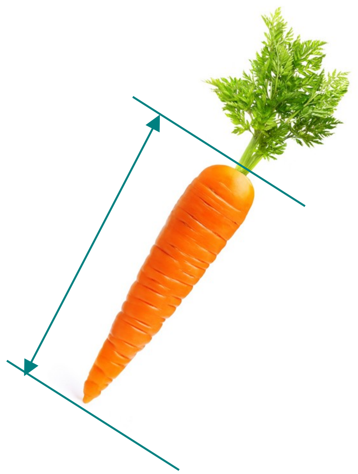
Process capability

Imagine you're managing a pack house that processes carrots. Your customer has specified items with lengths 10 +/- 0.8 cm. These are the lengths found in a sample (in cms):

10.2	**10.1**	**10.1**	**9.8**	**10.4**	**10.8**	**9.9**	**9.8**	**9.8**	**10.3**	**10.6**

What proportion of production would you want within the specified limits?

A. 50% at least
B. More than 99%
C. 100% and nothing less
D. Doesn't apply to me as I will never work in a carrot packing house

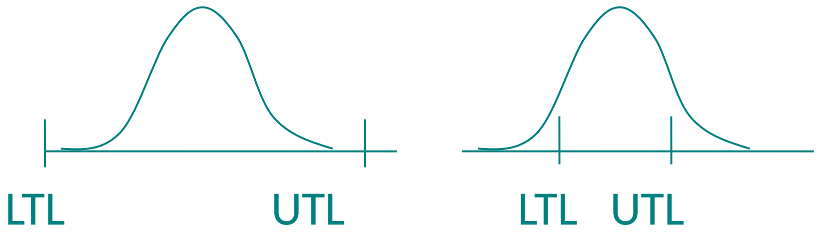


Process capability

We use *process capability* to define acceptable variation

- By expressing upper and lower *tolerance limits* UTL, LTL
- Then finding the standard deviation *s* of a sample
- Then testing whether (mean +/- 3*s*) falls within tolerance limits
- Because *99.7%* of observations fall within (mean +/- 3*s*)

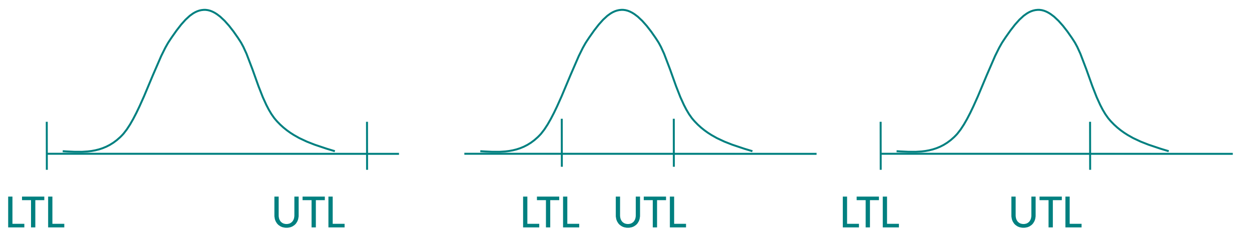
  ...on a normal distribution
- In the simplest case we calculate C_p = (UTL – LTL) / 6*s*
- If C_p < 1 then process is 'incapable'



Process capability

But if the sample doesn't fall evenly between UTL and LTL:

- We need to look either side of the mean $\bar{X}$
- Then the upper 1-sided index $C_{pu} = (UTL - \bar{X}) / 3s$
- And the lower 1-sided index $C_{pl} = (\bar{X} - LTL) / 3s$
- The Net index $C_{pk} = \min(C_{pu}, C_{pl})$



Process capability

Example

- If filling packs have a specification (214, 198) and a process standard deviation (s) = 2

- Then process capability C_p = (UTL – LTL) / 6s = 16/12 = 1.33

- If process average was 210
  - C_{pu} = (214 – 210) / (3 x 2) = 0.67
  - C_{pl} = (210 – 198) / (3 x 2) = 2.0
  - C_{pk} = min(C_{pu}, C_{pl}) = 0.67

C_{pu} = (UTL – $\bar{X}$) / 3s
C_{pl} = ($\bar{X}$ - LTL) / 3s
C_{pk} = min (C_{pu}, C_{pl})

- We'd know the distribution wasn't centrally between the tolerance limits

Quiz

An Internet service provider provides a mean communication rate of 1 Mbps to its domestic customers, with a standard deviation of 0.2 Mbps; what lower tolerance limit can it set, and still have an acceptable process capability?

A. 0.4 Mbps
B. 0.3 Mbps
C. 0.2 Mbps
D. Doesn’t matter because no one checks this

Quality Management

Controlling variation and meeting expectation

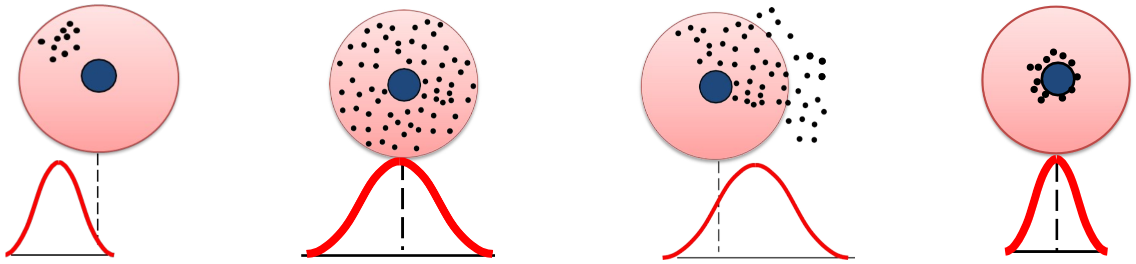
Part 3: Control charts

Reminder: Controlling quality: SPC

2 main elements

- Removing enough variation to meet functional need
  - Apply *tolerance limits*, and adjusting the process until the sample distribution fits between these limits

- Ensuring variation is *not reintroduced* in the process
  - By charting variation over time, and applying *control limits*
  - Testing observations against the limits



Reminder: Process capability

Example

- Specification (214, 198)
- Standard deviation (s) = 2

- Process variability= 6s = 6 x 2 = 12
- Process capability C_p = (UTL – LTL) / 6s = 16/12 = 1.33

- If process average was 210
  - C_{pu} = (214 – 210) / (3 x 2) = 0.67
  - C_{pl} = (210 – 198) / (3 x 2) = 2.0
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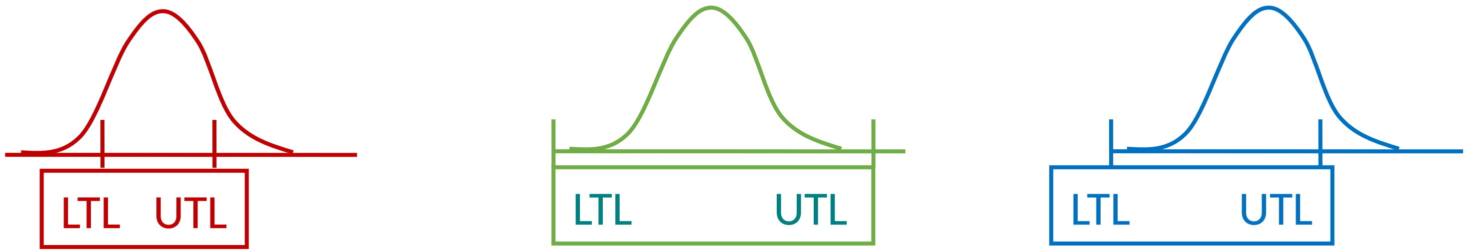


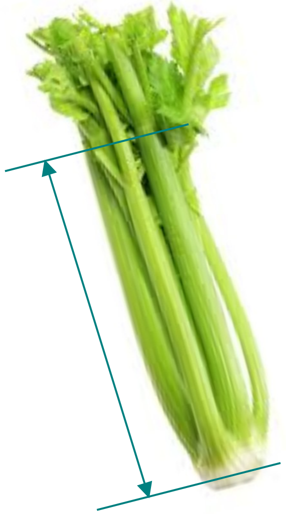
C_{pu} = (UTL – $\bar{X}$) / 3s
C_{pl} = ($\bar{X}$ - LTL) / 3s
C_{pk} = min (C_{pu}, C_{pl})

Control charts

Now imagine you're managing a pack house that processes celery

- Your process has been producing acceptable outputs
  - Process capability has been acceptable
  - No obvious sources of variation can easily be eliminated
  - You measure a succession of items coming off the line (all in cm)

19.8	**19.7**	**20.1**	**19.8**	**20.0**	**19.7**	**19.9**	**20.2**	**20.3**	**19.9**



- The next item is 21.3 cm

What does this latest measurement tell us?

A) The process is continuing to show its normal and acceptable variation

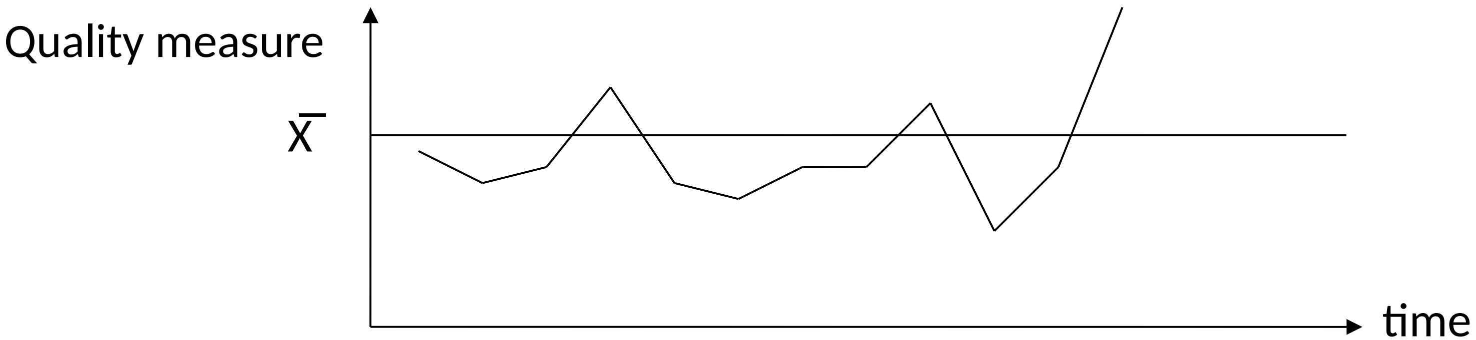
B) A new source of variation has probably entered the system

C) Doesn't apply to me as I will never work in a celery packing house

D) I'll fire the people on the processing line for this error

Control charts

- Sample measurements plotted sequentially (usually in real time)
- At each measurement, we ask if the process has changed
- We answer this by testing if the last point is so different that it's very unlikely to have come from the same distribution



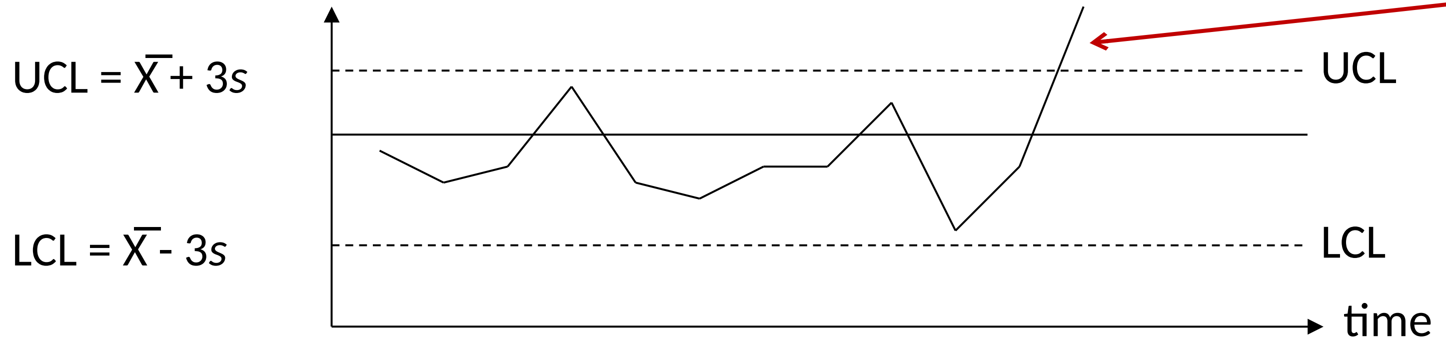
Control charts

How we make the judgment of whether the process has changed:

- We set upper and lower control limits UCL and LCL
- Which are set at +/- 3s from the mean
- And then we see if the process crosses either of these control limits
- *If* the process hasn't changed the probability of this is 0.003, i.e. very low

(because 99.7% of values in a normal distribution will fall +/- 3s from the mean)

- *So* we can be pretty sure the process has changed



Control charts

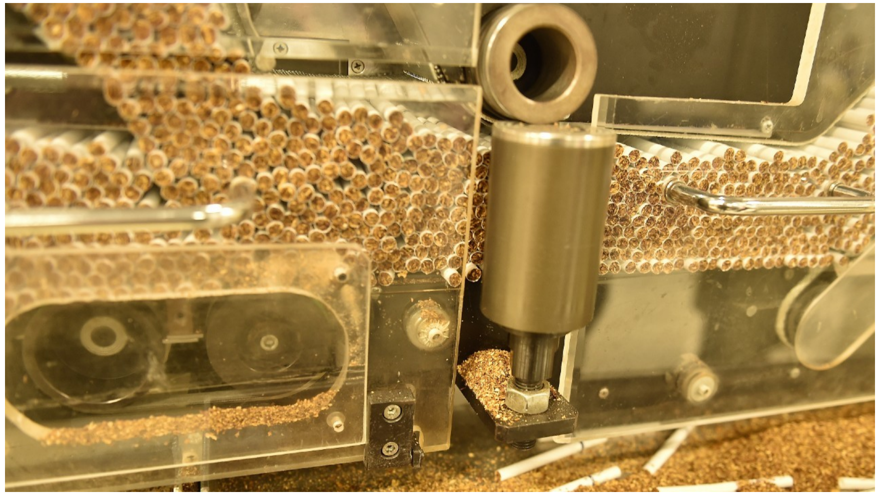
- Why is the test based on +/- 3 standard deviations?
  - It's a convention, as in most operations this provides a good enough standard
  - But really you need to think of the cost of
    - false positives (saying the process is out of control when it isn't)
    - false negatives (saying the process is not out of control when it is)
- Type I error (false positive)
  - We wrongly think the process *has* changed
  - So intervene unnecessarily
  - Cost: downtime, disruption…
- Type II error (false negative)
  - We wrongly think the process *has not* changed
  - So fail to intervene when need to
  - Cost: severe failure, bad output, defecting customers…

Control charts

In practice, we use Mean-Range charts

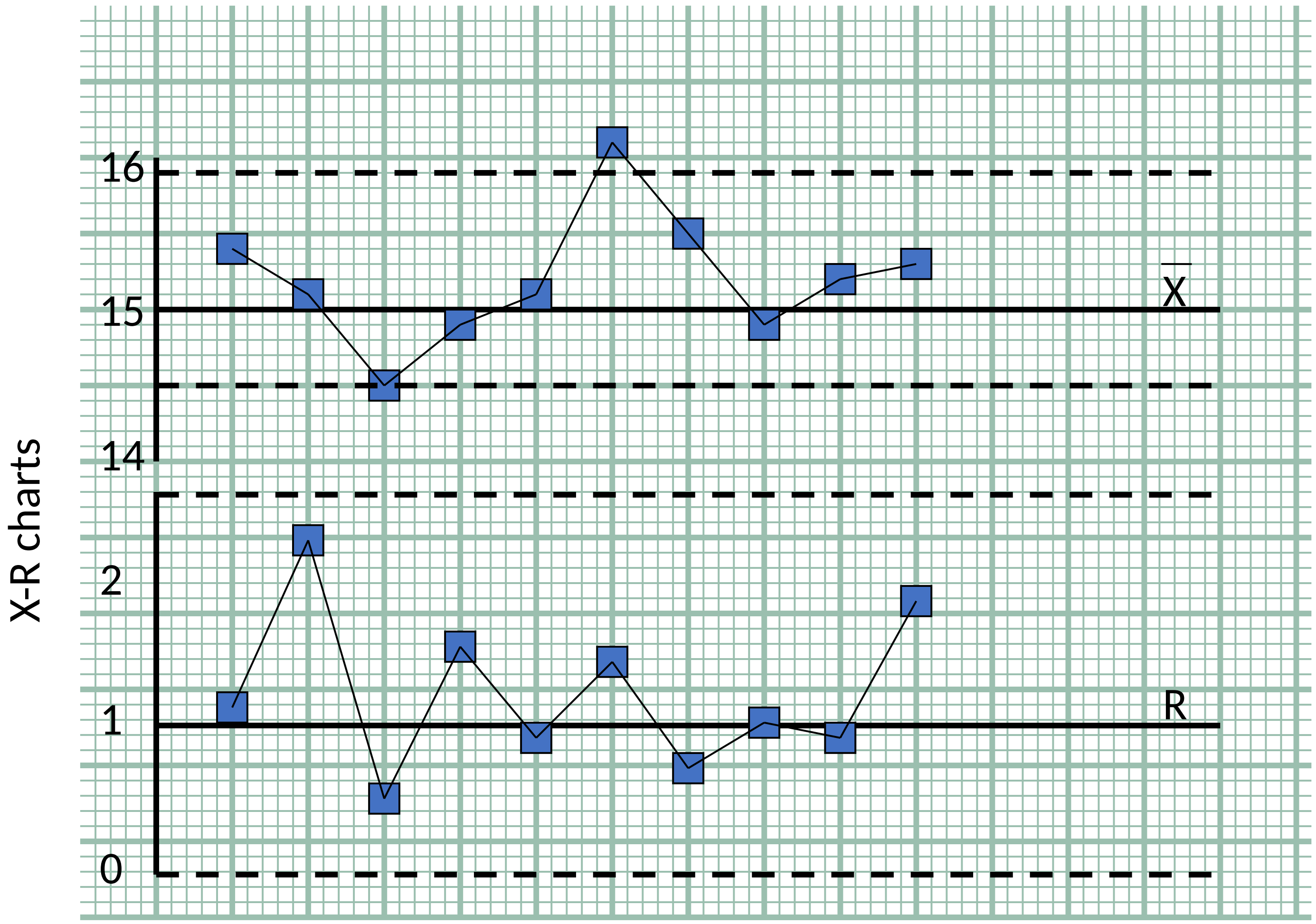
- So if we produce 1,000 items per/min measuring every one may be infeasible
- Therefore most operations would sample, e.g. 10 items out of 1000 / min
- And then use the mean and the range of the sample as quality measures
- These would each be plotted on a control chart as each sample was produced

- This allows 2 measures and 2 charts:
  - Sample means
  - Sample ranges



Control charts

- Typically the means chart is plotted above the ranges chart:
  - This example shows means going out of control early in the period



Control charts

N	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.58
4	.729	0	2.28
5	.577	0	2.12
6	.483	0	2.00
7	…		

- Finding Mean-Range chart control limits doesn't directly use standard deviations
- For the means chart:
  - Find the mean of past sample means, the grand mean $\bar{\bar{X}}$ = mean ($\bar{X}_1$, $\bar{X}_2$, …)
  - Find the mean of all past sample ranges, the mean range $\bar{R}$ = mean (R_1, R_2, …)
  - Then you need to look up a constant called A_2
  - This comes from a table where you use the number of items in a sample N
  - Look along the row with the N you're using to find A_2
  - E.g. if our samples had 4 items in them, the value of A_2 is 0.729
  - Then you find the control limits as $UCL = \bar{\bar{X}} + A_2 \bar{R}$; $LCL = \bar{\bar{X}} - A_2 \bar{R}$

Control charts

- For the ranges chart:
  - First you need to look up 2 constants called D_3 and D_4
  - E.g. with a sample size of 4 these values are 0 and 2.28
  - Then you find the control limits as $UCL = D_4 \bar{R}$; $LCL = D_3 \bar{R}$

N	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.58
4	.729	0	2.28
5	.577	0	2.12
6	.483	0	2.00
7	…		

Note:

- The control chart constants will be provided to you
- The control chart constants are also freely available on the internet and in your textbook

Control charts

Example: SPC at GAM (Slack et al)

- Contract cosmetics mfg. company
- Operating a cosmetics filling and sealing line
- Tightness of cap as control to avoid leakage/cracking
- Samples of 4 containers
- Grand mean = 812 units
- Average range = 6 units
- Means UCL = 812 + (0.729 x 6) = 816.4
- Means LCL = = 812 - (0.729 x 6) = 807.6
- Ranges UCL = 2.28 x 6 = 13.7
- Ranges LCL = 0 x 6 = 0

For Means Chart:

$$\text{Upper control limit (UCL)} = \overline{\overline{X}} + A_2\overline{R}$$
$$\text{Lower control limit (LCL)} = \overline{\overline{X}} - A_2\overline{R}$$

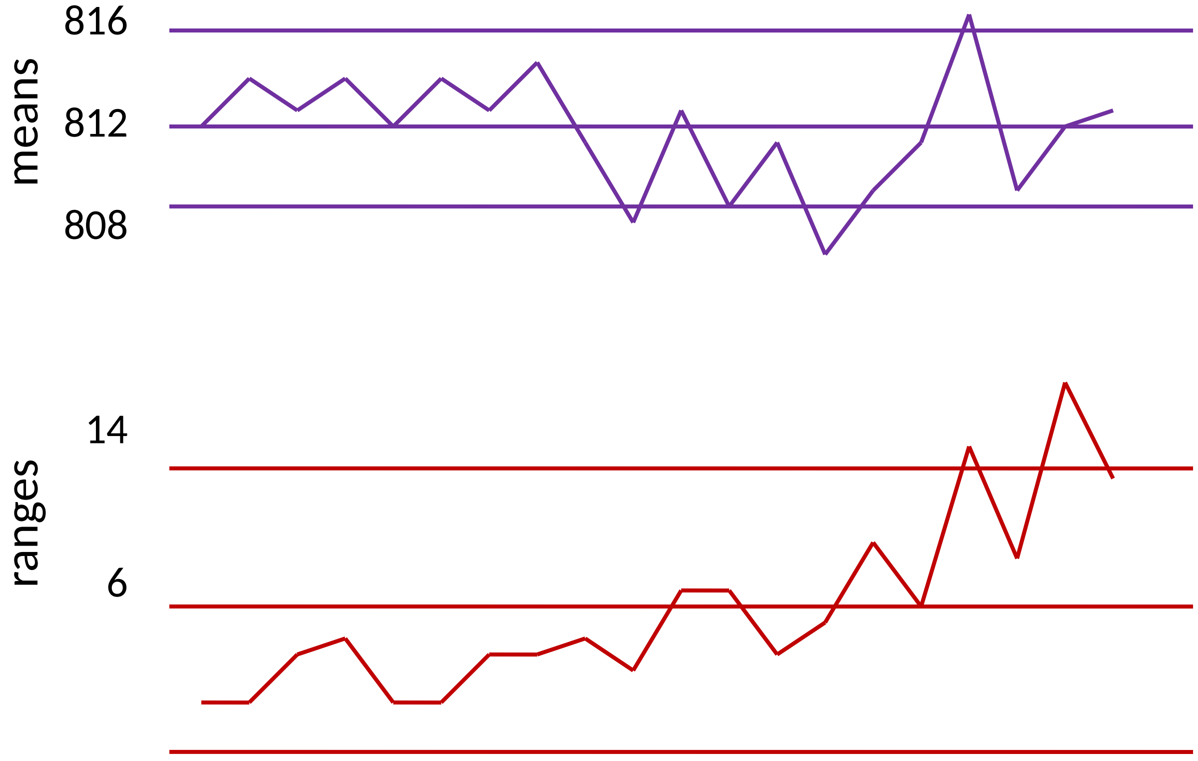
For Range Chart:

$$\text{Upper control limit (UCL)} = D_4\overline{R}$$
$$\text{Lower control limit (LCL)} = D_3\overline{R}$$

N	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.58
4	.729	0	2.28
5	.577	0	2.12
6	.483	0	2.00
7	...		

Control charts

- If you plot the data given in the textbook against the control limits the chart looks like this, indicating a process going out of control:



Quiz

- Samples of 10 exam marks are taken from 5 successive exams at the start of a programme of exams. The mean marks of the samples were **61, 59, 60, 62, 63**, and the ranges for the samples were **11, 10, 7, 12, 10**.
- If the next sample has a mean of 65 has the process gone out of control?

A. No

B. Yes

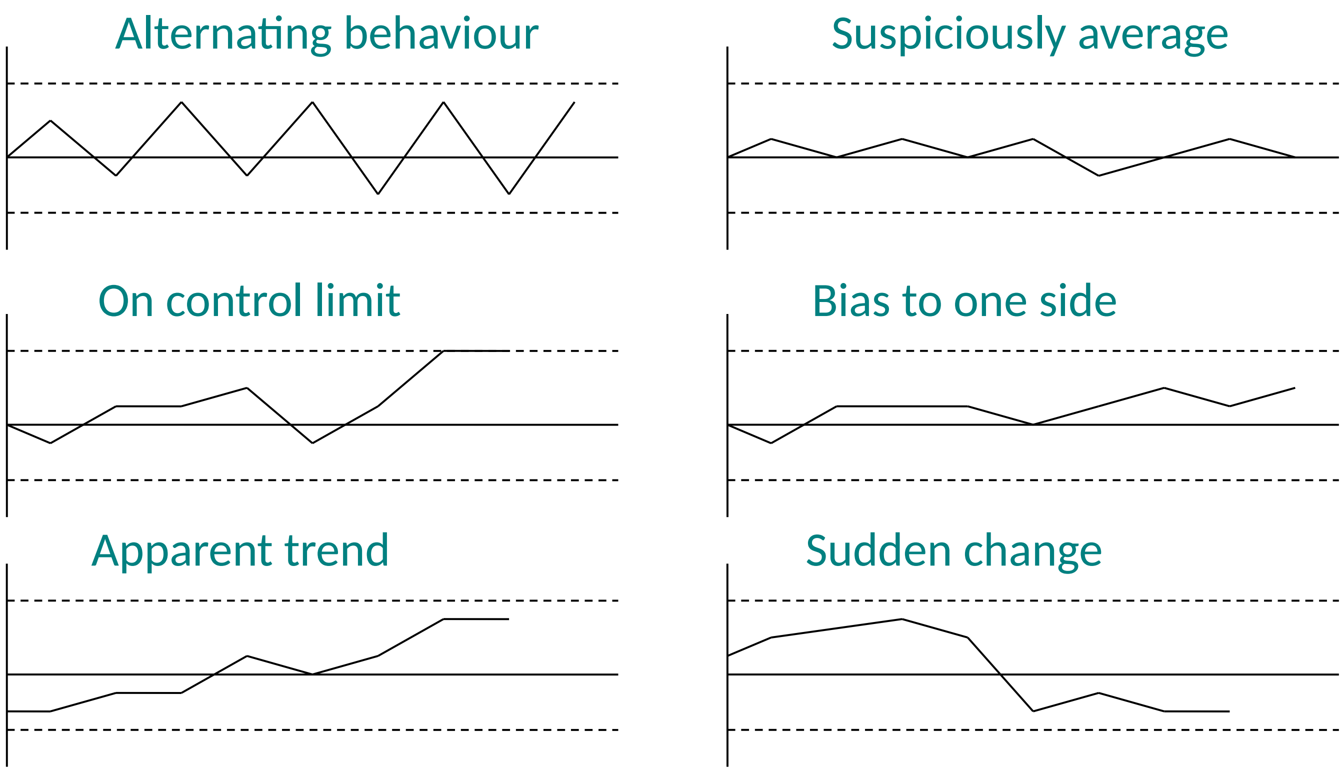
C. Don’t know, don’t care

D. Maybe, not sure

Subgroup size (n)	A2	D3	D4
2	1.880	0	3.267
3	1.023	0	2.574
4	0.729	0	2.282
5	0.577	0	2.115
6	0.483	0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864
9	0.337	0.184	1.816
10	0.308	0.223	1.777
15	0.223	0.347	1.653
25	0.153	0.459	1.541

Control charts interpretation

- In practice the charts provide useful graphical information
- The following indicate some possible patterns



Quality Management

Controlling variation and meeting expectation

Part 4: Total quality management

Managing quality

- Now we broaden the idea of quality beyond controlling variation
- Which of the following is the best definition of quality for you?

A. Quality is conforming to a specification

B. Quality is being appropriate to the price being charged

C. Quality is having the right set of characteristics

D. Quality is fitness for purpose

E. Quality is innate excellence

Managing quality

- Garvin produced 5 approaches to defining quality along these lines
- First, manufacturing-based quality
  - This is quality as conformance to a specification
  - It assumes that the best output is specifiable
  - And it emphasises maintaining an existing standard
  - It's perhaps the most obvious way to define quality for a complex product

Managing quality

- Second came value-based quality
  - This is quality as price-appropriateness
  - It emphasises the trade-off between price and specification
  - And it assumes customer acceptance of the trade-off
  - This might not be true for medications where even cheap products should be safe
- Then came product-based quality
  - This is quality as a precise set of characteristics
  - It unpacks quality into different aspects e.g. functionality, aesthetics
  - So it emphasises exhaustive analysis of a product or (possibly) service
  - And it assumes quality is decomposable in this sense: a sum of the parts

Managing quality

- But these 3 are producer-oriented, so then came user-based quality
  - This is quality as fitness for purpose
  - The emphasis is on function from the user’s standpoint
  - Although there is still an assumption of a specifiable need
- The final definition drops the idea of specification: transcendent quality
  - This is quality as innate excellence
  - It emphasises association with a brand
  - And it emphasises expectation not specification
  - In some ways it’s the least satisfactory yet the most realistic

Managing quality

- Generally, the following definition is useful:
  - Consistent conformance to customer expectations
  - It is therefore indicating that 'Consistency' is what matters, not e.g. brilliance
  - And that the 'Customer' is the key subject, not the producer
  - And that 'Expectations' are the defining standard, not some prior standard

Managing quality

- But even with this definition there are difficulties…for e.g. –
- In educational services (like this one) you could ask several questions
  - Are customer expectations really well-formed at the start?
    - Do customers necessarily know what to expect from university education?
  - Should we treat customer expectations as entitlements?
    - Isn’t a qualification a joint outcome of learner and educator effort?
  - Is consistency an over-riding criterion?
    - Don’t standardised processes create both a floor and ceiling to performance?
  - And who’s the real customer? (i.e. employers, parents, the government, or you?

Managing quality

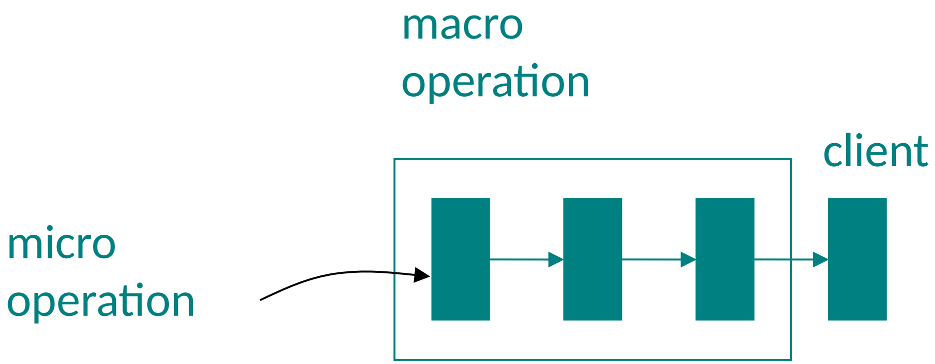
- The concern with customers, expectations etc. led to Total Quality Management
- TQM emerged as a management programme in the 1980s/90s
- It reflected changing circumstances in much of industry…
  - The early stress on competition through price & strong pursuit of process economies
  - The later development of consumerism & increase in disposable wealth
  - And the increasing recognition of a whole operation's influence on quality

‘In autos… quality went from a low-ranking factor in consumer purchase decisions in the mid 1970s to one of the highest-ranking factors in the early 1980s’ (Cole, 2000)

Managing quality

TQM's main themes

- The first is customer viewpoint
- The principle is that the customer viewpoint is primary
  - And that their experience is part of the service or product
- Alongside this is the idea that all micro-operations have customers
  - Each satisfies the final customer by satisfying internal customers
  - So micro-operations must manage customer relations

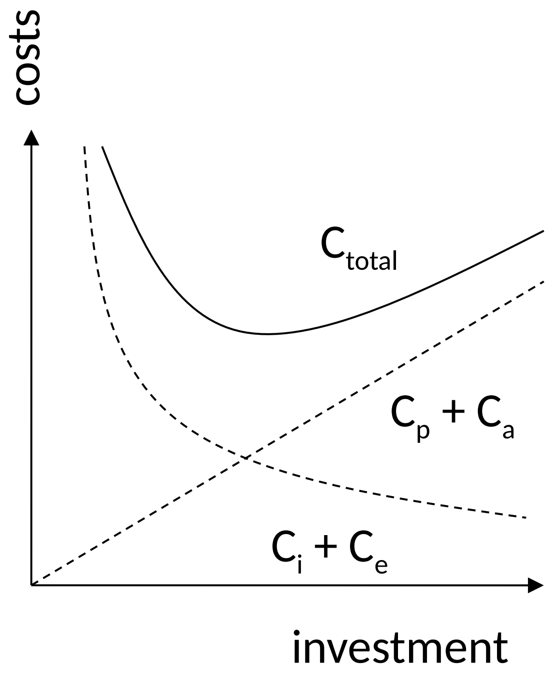


Managing quality

- A second principle is comprehensive participation
- This is based on the observations that…
  - Responsibility for quality should be collective
  - Problem solving should be collective
  - Employees should be empowered to exercise initiative
  - Suppliers should be involved in quality improved, and helped to develop

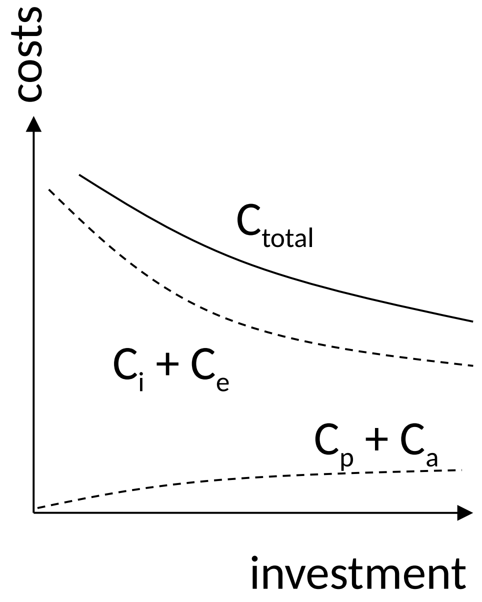
Managing quality

- A third principle is true costs of failure
- The usual analysis of the costs of quality has 4 components:
  - Prevention costs (e.g. training people thoroughly) C_p
  - Appraisal costs (e.g. inspecting products or services) C_a
  - Internal failure costs (e.g. rectification of faulty products) C_i
  - External failure costs (e.g. meeting warranty costs) C_e
- The traditional logic is one of trade-offs:
  - We trade off C_p and C_a against C_i and C_e
- So as we invest more in quality we decrease one cost
  - But increase another



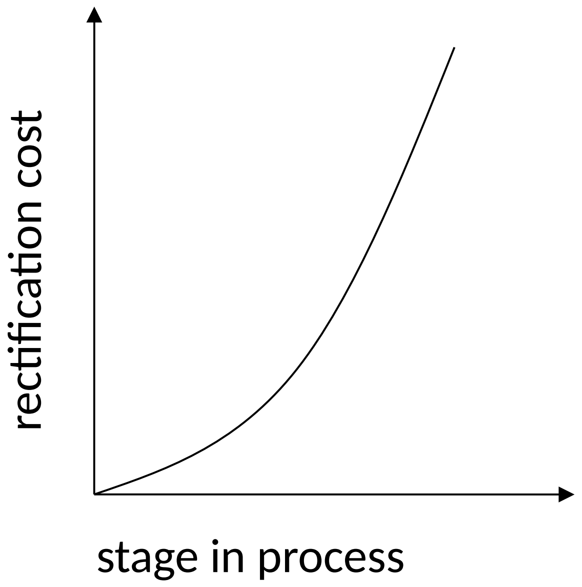
Managing quality

- TQM says this is wrong
  - Failure costs are grossly underestimated
  - E.g. we don't realise the costs of defecting customers
  - Prevention costs are typically overstated
  - E.g. we think we have to employ more inspectors for better quality
  - So there is no trough in the total cost curve



Managing quality

- A fourth principle is right first-time processes
- So it stresses 'Right first time' not 'as fast as possible'
- E.g. you should spend effort on 'fool-proofing' to avoid failure
- It's important to realise that rectification doesn't just incur same cost twice
- And that rectification gets costlier the later it occurs



An example

- *The truth about the Xbox 360* (Guardian, 12/11/08), suggesting even highly intelligent, technically sophisticated people sometimes forget this principle

“The infamous Xbox 360 "red ring of death" (indicating a failed unit) has caused Microsoft - and its customers - untold pain… and cost it \$1.15bn (£738m) last year… poor production quality was at the heart of the failures…… When production results are really off-kilter, stopping a line and tracing a problem back to its roots is the answer. But the decision was made to carry on…

Managing quality

- A fifth principle is quality systems
- This says that problems and failures are always systemic
  - Blaming ‘operators’ is easy and normal
  - But it’s fundamentally inaccurate
- And its says that quality systems are needed to embed TQM in a firm
  - To define a policy, state procedures & responsibilities
  - To give detailed work instructions & methods
  - To specify procedures for continuous improvement

Managing quality

- Customer viewpoint seems like an obvious principle, so why does TQM has to make this point? Is it for example…
  A. Because organizations find it too hard to respond to customers' needs?
  B. Because organizations believe customers do not really know what they want?
  C. Because organizations have systems that become so complex that people do what the systems want and not what customers require them to do?
  D. Because no one knows who is doing what in organisations anyway?

Managing quality

- Again, comprehensive participation seems like an obvious principle. So why does TQM has to make this point? Is it for example…
  A. Because managers lack insight into how people contribute to a product's or service's quality?
  B. Because managers suspect suppliers will exploit their help in ways that doesn't benefit managers?
  C. Because legal contracts generally forbid close negotiation or disclosure between buyers and suppliers?
  D. Because no one knows who is doing what or why in organisations anyway?

Managing quality

But this raises an important question: are the 1st & last themes (focusing on customers & having a quality system) contradictory?

A. No: A good system mean that a customer focus is properly embedded in the way an operation works

B. Yes: systems detract from customer focus because systems go wrong all the time

C. Unclear: it is too vague to say one way or the other

D. I’ve had enough of TQM to be honest

Questions

Thank you