Ollscoil Teicneolaíochta an Atlantaigh

Atlantic Technological University

Lean Sigma BIO 08025

Lecture 3

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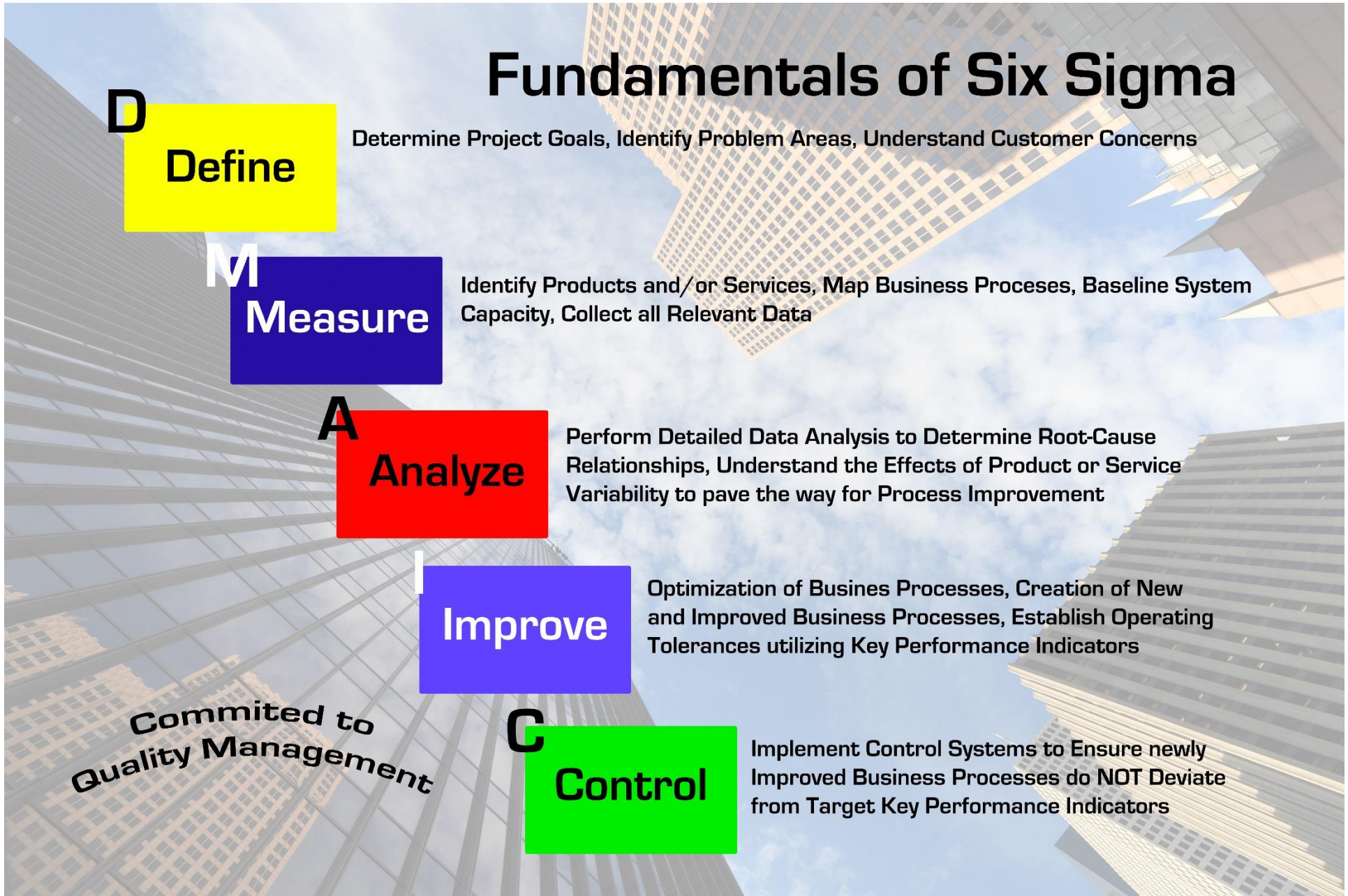
Lecture Summary

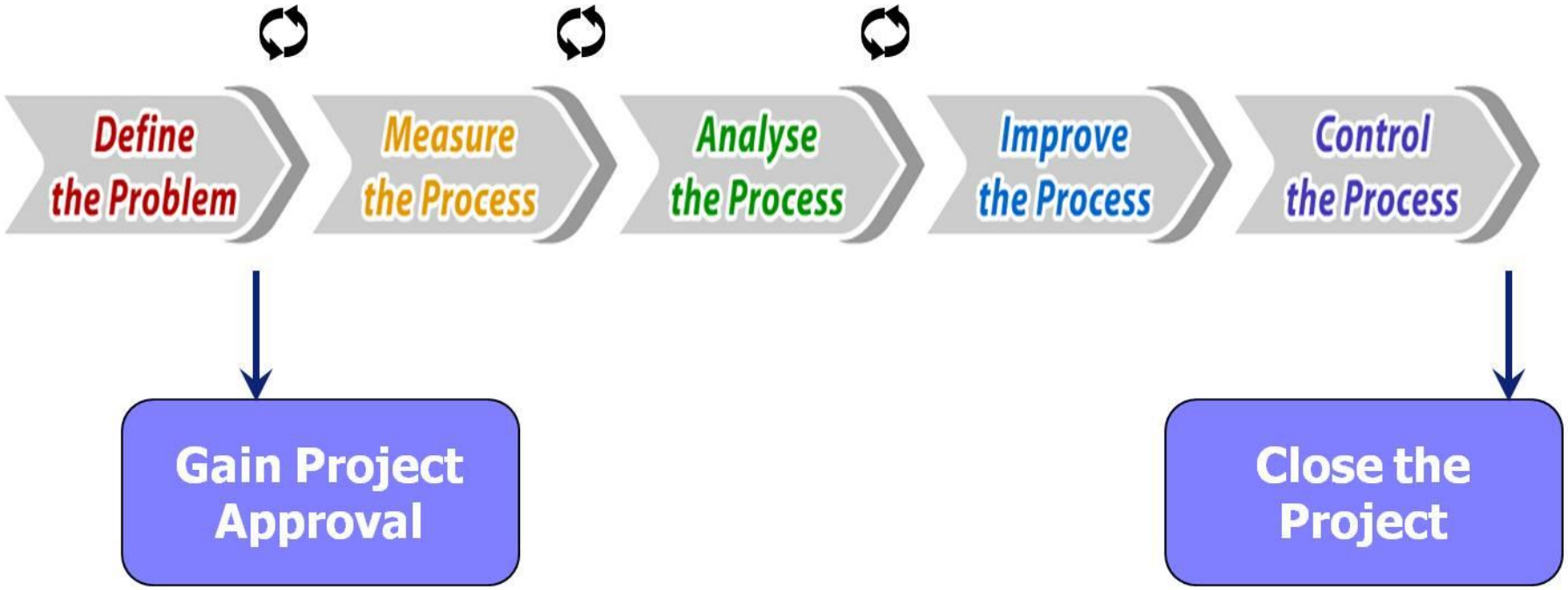
- DMAIC Process Overview
- Cost of Quality

DMAIC Overview

Six Sigma – Cost of Quality



DMAIC – a logical flow to problem solving



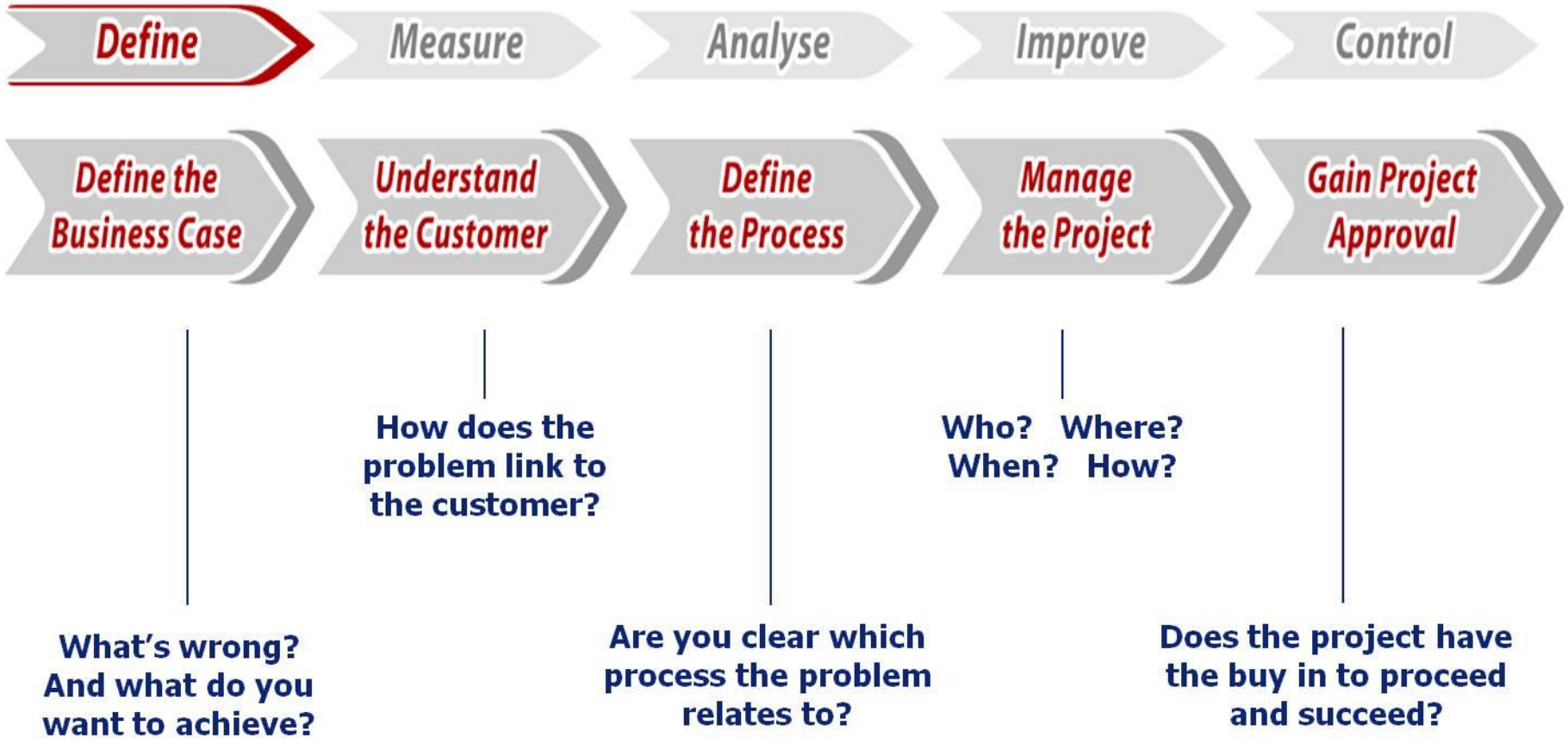
An iterative approach

DEFINE

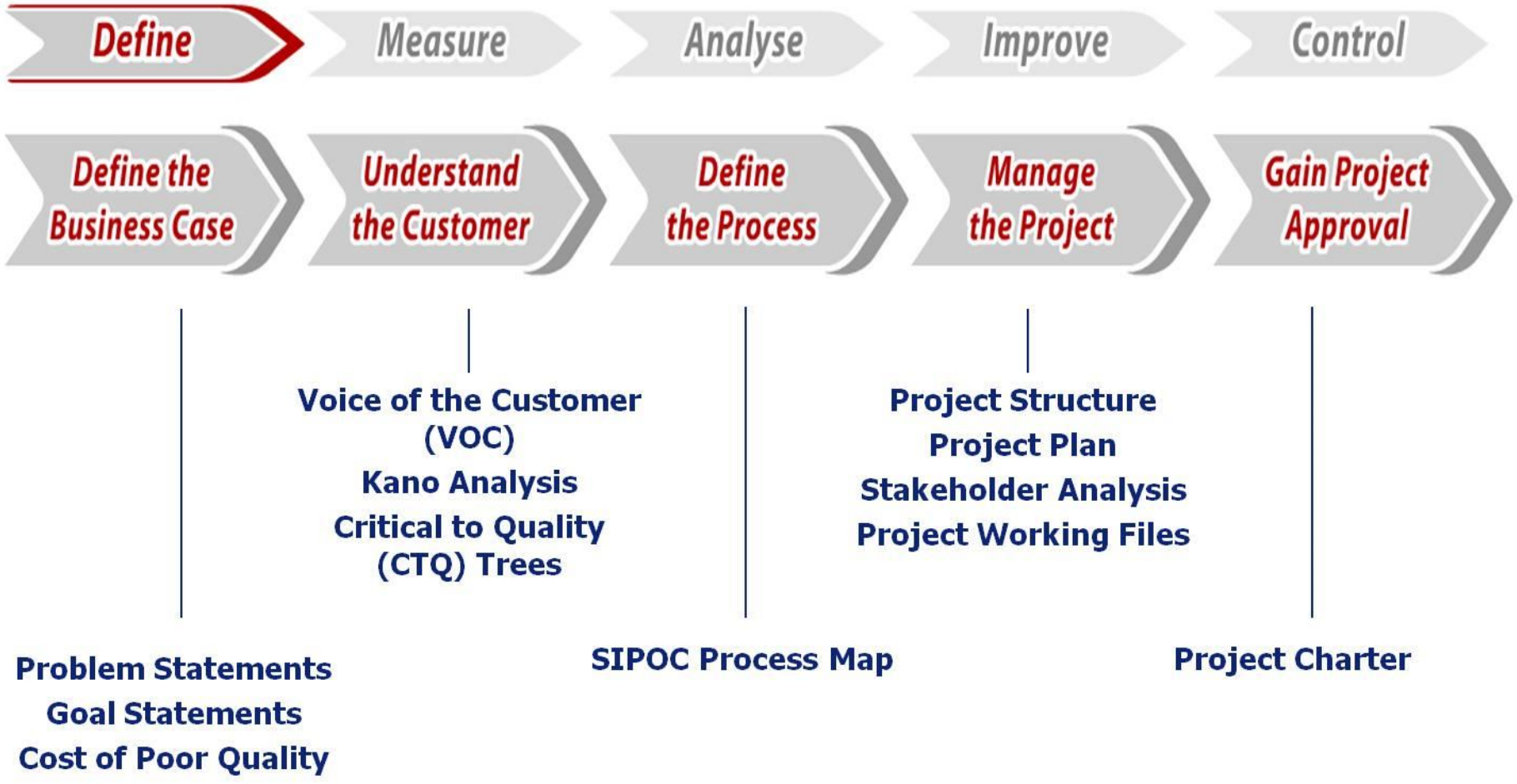
The focus of Define phase….

"to develop a clear project charter, based on a real problem that is relevant to the customer and that will provide significant benefits to the business"

The flow through the Define phase….



The tools through the Define phase….



Re-inventing the wheel?

- Many problems get solved only to reappear again later on
- Need a problem solving method
- DMAIC forces teams to
  - Confirm the nature and extent of the problem
  - Identify true causes of the problem
  - Find solutions that evidence shows are linked to the cause
  - Establish procedures for maintaining the solutions even after the project is done

Pre-Team

- Management team undergo *project selection process* to identify projects to launch

- Champion (Corporate Level Executive)
  - Help the supervisor/manager draft a project charter (1 to 2 pages) to document what they want the team to accomplish

Project Charter

- Captures the essence of a project
- Describes
  - What the team should accomplish
  - Who will work on the project
  - What roles they will have
  - Timelines
  - Other key information

Project Charter

- Draft document
- Team will be expected to fine tune it
- Discussion may change management's mind about the whole project
- Problem may be too big for the proposed team to handle
  - Reasonable goals will need to be refined with management

- Team needs to refer back to the charter throughout the project
  - Helps remind them what they're doing
  - Gives them a chance to update the charter as they learn more

Project Charter

Proposal Process Improvement

Description: Improve quality proposal development by defining a precise process, managing to the process, improving efficiency, and reducing cycle time such that we can accomplish 15% more proposal work without increasing budgets.

Background: Engineering analysis needs to be done up front. Using analysis, develop a clear understanding of work scope. Educate senior management on proposal content. Prepare team to write/estimate based on a clearly defined technical scope of work.

In Scope: Product line proposals

Out of Scope: Highly efficient quality proposals

KPOV: Proposal cost

Goals:

1. 15% reduction of proposal cost based on metrics derived from previous large scale proposals
2. Increase proposal capacity by 10% (no increase in budget)
3. Reduce rework in the writing process

Assumptions:

1. Improving efficiency and reducing cycle time will result in the ability to do 15% more proposal work within the same budget
2. Full time dedicated proposal manager
3. Move rework resources into up-front planning and education to realize back end savings

Other Benefits:

1. Improve quality of written material
2. A standard proposal process will improve training, repeatability, and employee efficiency
3. A database / archive of material that can be reused for future proposals

Role	Name	Utilization	Start	End
Project Champion	Blanck, Mike	50%	8/20/2002	1/11/2003
Black Belt	Parra, Derek	100%	8/20/2002	1/11/2003
Financial Approver	Martin, Rick	10%	9/24/2002	1/11/2003
Team Member	Clark, Kathy	25%	8/20/2002	1/11/2003
Team Member	Robert, Rene	25%	8/20/2002	1/11/2003
Project Sponsor	Raney, Al	10%	8/20/2002	1/11/2003

Define-M-A-I-C

First stage;

- Team & sponsors need to agree on the project

- **Examples**
  - Discussing the project character as a team
  - Getting Customer data
  - Review existing data about the process/problem
  - Draft a high-level map of the process
  - Setting up a plan & guidelines for the team

Why do this?

- Develop a *shared* understanding of the business priorities for your project
- Confirm the opportunity
- Reach agreement with management on a *realistic* scope for the project
- Agree on how “success” will be measured
- Set the team up for success

SIPOC

- **Defects** can relate to anything that can make a customer unhappy
- Therefore need to take a process view of how the company satisfies the customer's needs
- SIPOC
  - High level process map tool

SIPOC

- **S**uppliers
  - Individuals/groups whoever provide whatever is worked on in the process
- **I**nput
  - All inputs to the process i.e. materials, forms, information etc.
- **P**rocess
  - One block showing the steps used to do the work
- **O**utput
  - The product, service, or information being sent to the customer (internal or external)
- **C**ustomers
  - The next step in the process (internal) or the final (external) customers

A high-level SIPOC chart helps visualize the Voice of the Customer and begin to see the relationships between the outputs and the inputs of the process

SIPOC				
Suppliers (resource provider)	**Inputs** (to the process)	**Process** (high level process flow)	**Outputs** (from the process)	**Customers** (receiver an output from the process)
Coffeemaker purchased - on countertop	>5 cup capacity coffee maker	**Making coffee**	heating to keep coffee warm for 1 hour after brewing	All of us enjoy the same brand of coffee with varying condiments
city water supply into faucet	water supply	Add water	enough coffee to serve all of us within 15 minutes of start time.	1 cup of coffee — wife
purchase from XYZ company	1 filter	Add filter & ground coffee	one filter to prevent overflow	1 teaspoon of french vanilla creamer — wife
Use ABC brand beans	4 tablespoons of coffee grinds		correct amount of grinds	
Electric company	120V GFCI outlet	Plug-in and turn on		1 cup of coffee — husband
Upper left drawer next to refrigerator	measuring spoons		Source to heat water to temperature	Honey on the table — husband
			Pump to move water up through filter.	Dash of cinnamon — husband
Mugs purchased - in upper left cabinet	coffee mugs	Pour into mug	Hot coffee filled near the top of the mug.	
refrigerator and pantry	condiments and containers for sugar, creamer, honey, cinnamon.	Add condiments		1 small cup of coffee for each
ABC brand for sugar & creamer.			coffee served in spouses favorite mug	1 teaspoon sugar
XYZ brand for honey and cinnamon		Stir	coffee served in husbands mug	1 tablespoon french vanilla creamer
pantry	stirrers, lids	Serve	coffee served in personalized kids mugs	Let sit for 5 minutes before serving — 2 teenagers

Coffee Making

SIPOC diagrams

- Simple process view
- Very useful for visually presenting the basic elements of a process
- Don’t really help a team understand what needs to be changed in a process
- Need more detailed maps such as “flowcharts”

D-MEASURE-A-I-C

D-MEASURE-A-I-C

- Measure is the heart of what makes the Lean Six Sigma work when other approaches haven't

- **If you don't gather data**

  - End up with a lot of quick-hit projects with short-lived or disappointing results

Measure

- Evaluate the existing measurement system
  - Improving it if necessary
  - Develop a measurement system of you don’t already have one
  - Observe the process
  - Gather data
  - Map the process in more depth

….necessary so that you can…

- TRUST your data
  - Unreliable measurement system?
- Base decisions on facts & reality
  - Opinions count but this is a data based system
- Document what's REALLY going on in the process
  - Develop a full understanding of what everybody does
- Understand what's important to improve
  - Which are the important steps?

Examples of Measurement Tools

- Process Observation
  - “You can observe a lot just by watching” Yogi Berra
- Value Stream Maps
  - Looks at how time is spent on a process
- Time series plots
  - Data points are plotted in sequence along a timeline
- Pareto charts
  - In the past general solutions to general problems
  - DMAIC uses data to pin-point a specific cause and then specific solutions

What is a Value Stream?

All the actions currently required to bring a product through the main flows essential to every product:

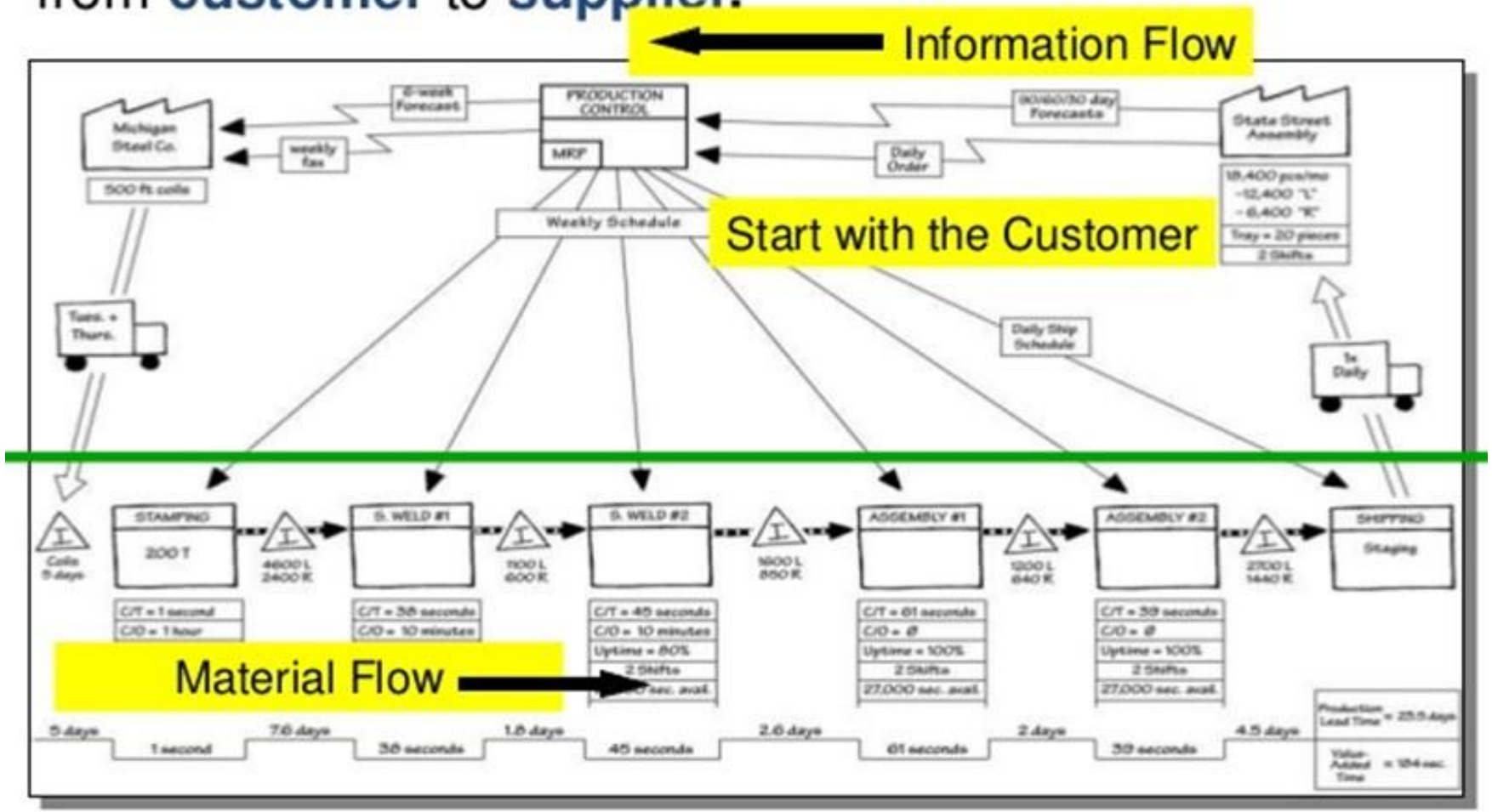
- the production and information flow from raw
- material to the customer
- the design flow from concept to launch
- Includes both value added and non-value
- added steps

Value Stream Map

- Shows the process flow
- Displays actual process data
- As they include data, they help teams pick out specific process points that have problems such as long wait times or lots of errors

What is a Value Stream Map?

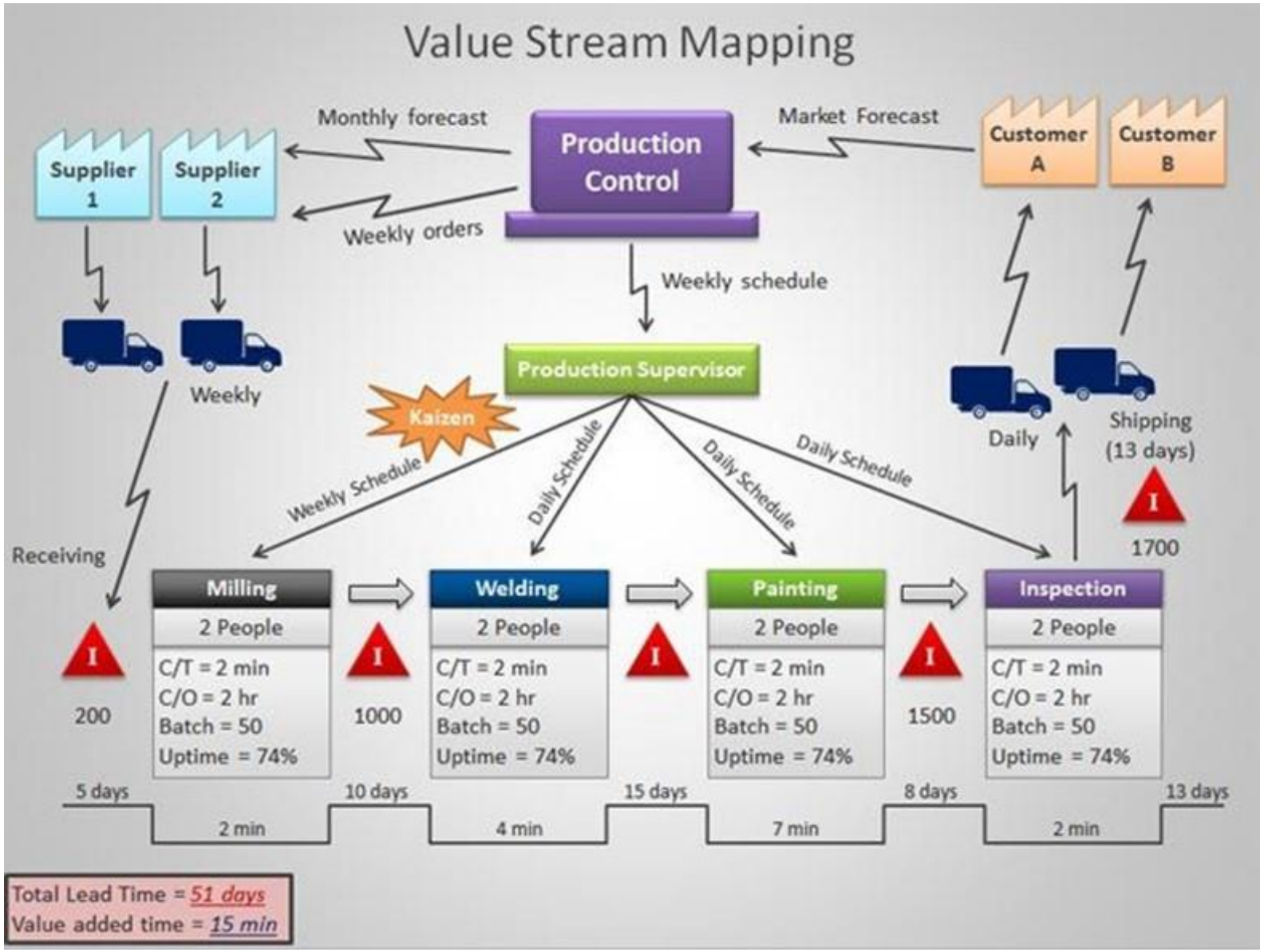
A **visual representation** of every **process** in the **material** and **information flow** of a product's path from **customer** to **supplier.**



The Importance of Value Stream Mapping

- Understand strategic business objectives
- Create High-level value stream map
    - Include high level business processes and high level metrics
- Collect additional metrics if warranted
- Analyse gaps to business strategy and voice of customer
- Decide on areas of focus
- Create project charters
- Accurately and Precisely DEFINE the problem
- MEASTURE the problem with Process and Value Stream Mapping
- Analyze the problem and focus on root causes
- Identify and prioritize IMPROVE tools and Implement
- CONTROL the solution and sustain the results

Value Stream Mapping

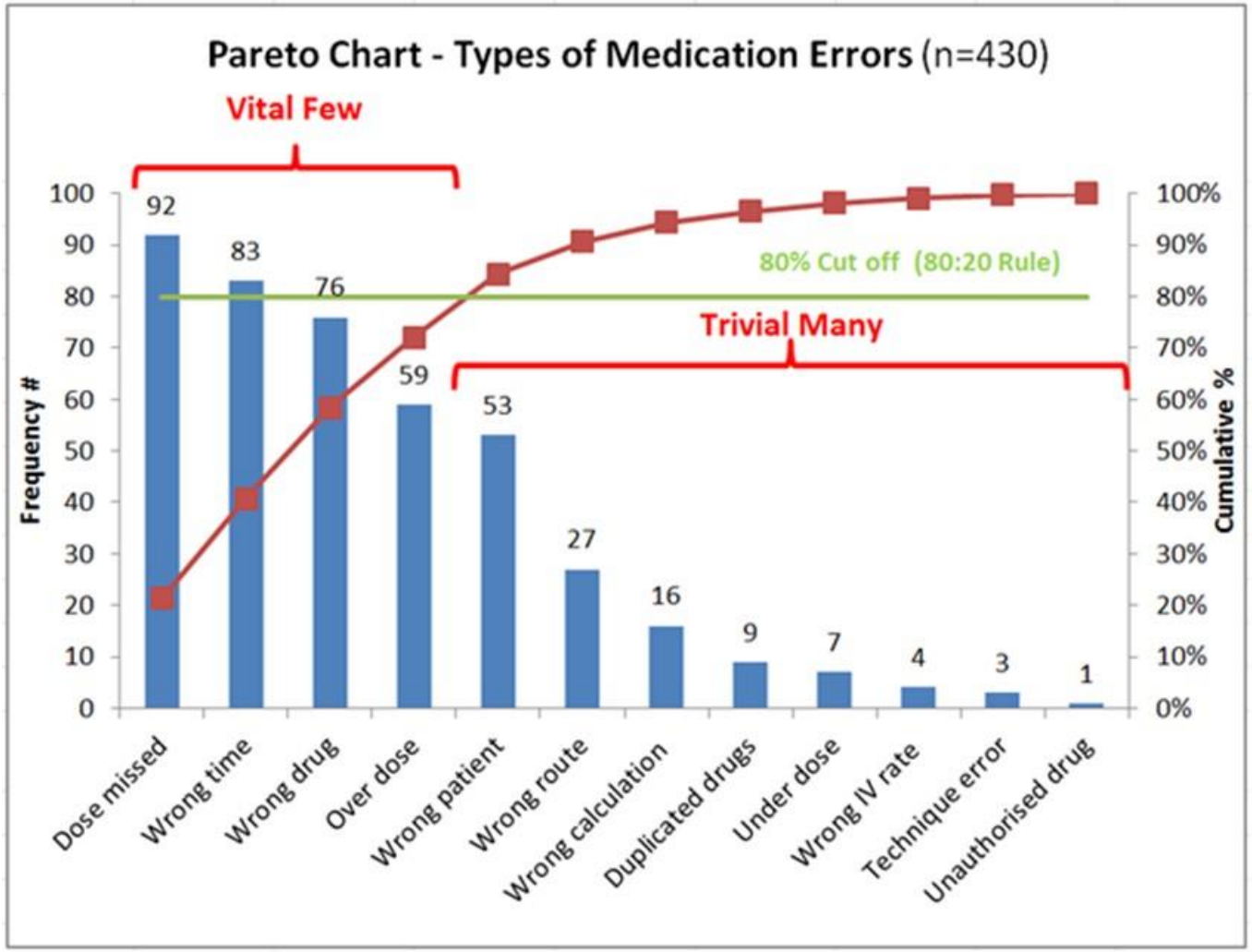


Pareto charts

- Used to focus a team's effort
- Each bar represents a different element of the problem
- Height of a bar shows how much the problem is due to that cause
- Bars are arranged in descending order
- Normally, the first few bars will be tall and the rest much shorter
- Therefore, you can *take care of most of the problem if you take care of the issues represented by the tall bars*
  - i.e. *focus* your efforts on the few biggest causes

- An 80% cut off line is also included to indicate where the 80/20 rule applies i.e. the vital few factors that warrant the most attention sit under the 80% cut off line.

Audit of Types of Medication Errors



D-M-ANALYSE-I-C

D-M-ANALYSE-I-C

- Analyse all the data collected in the “Measure phase”
- Use that data to confirm source of delays, waste & poor quality
- Teams must *stick to the data* and not opinions
- Data patterns?
- Targeting places where much time is wasted?

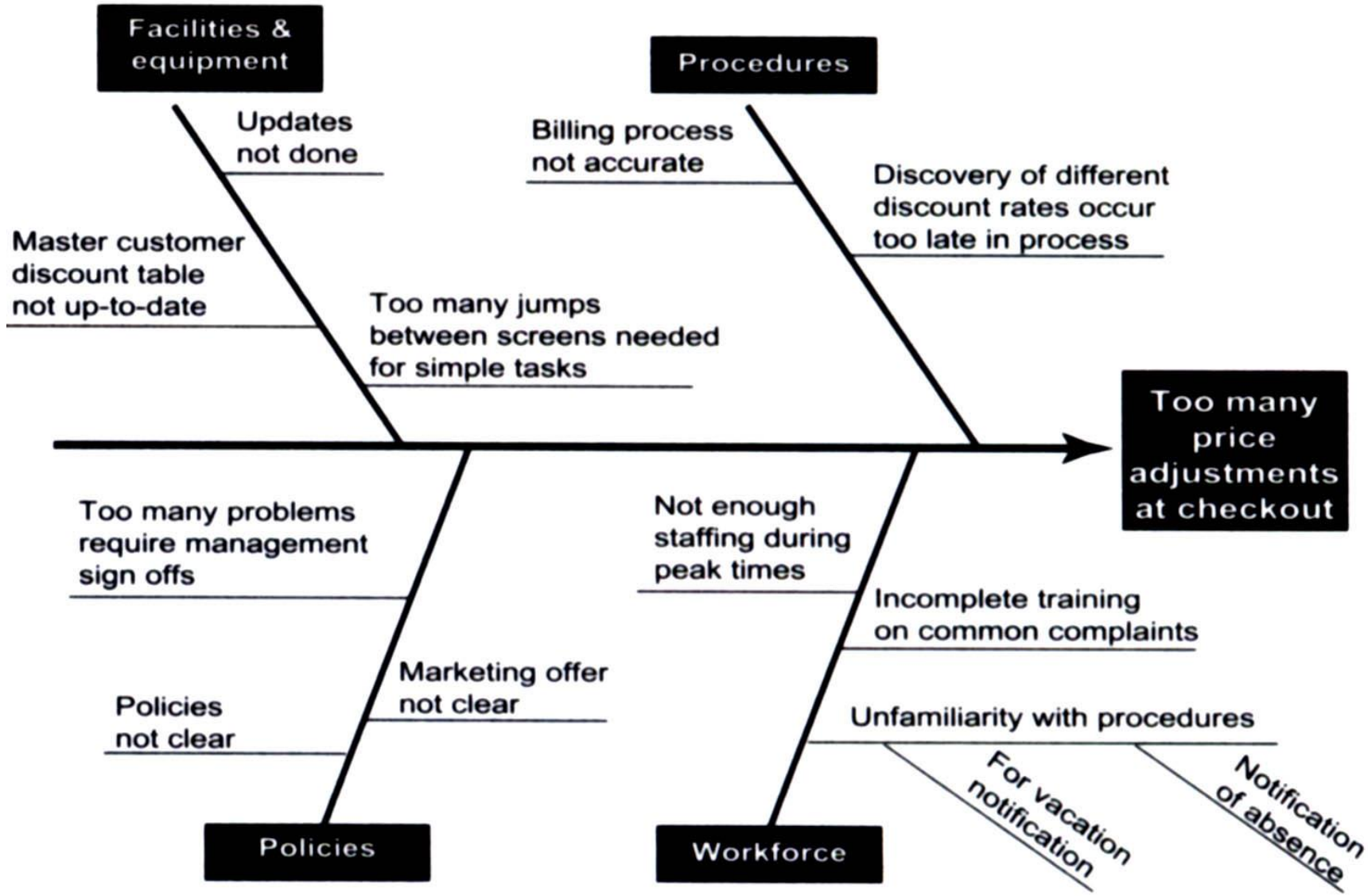
D-M-ANALYSE-I-C (continued)

- Find clues to REALS causes
- Find ways to make the process faster without sacrificing quality
- Identify critical process control factors

Analysis Tool examples

Cause-and-effect diagram (fishbone)

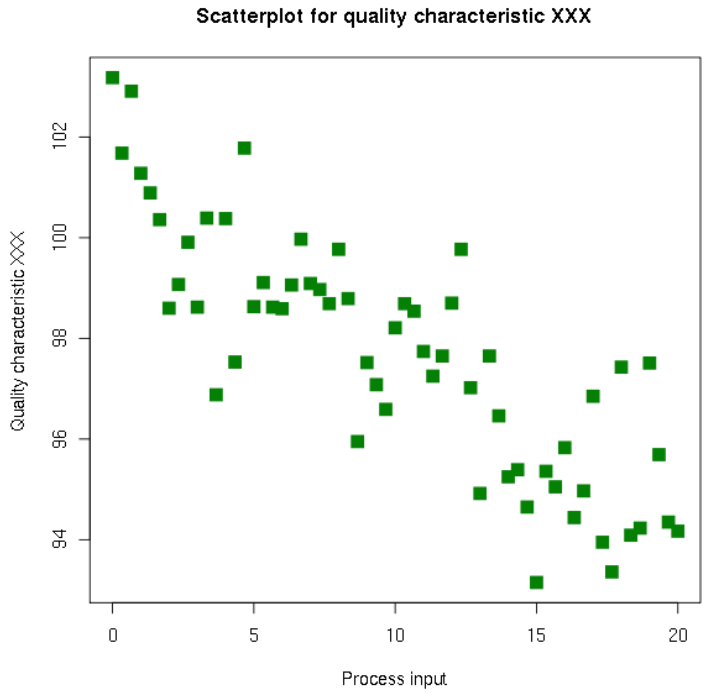
- Thinking tool that helps a team organise the ideas they have about potential causes of a problem
- It helps a team
  - make sure that they haven't overlooked potential causes
  - Decide which causes to investigate further


Facilities & equipment
Updates not done
Master customer discount table not up-to-date
Too many jumps between screens needed for simple tasks
Procedures
Billing process not accurate
Discovery of different discount rates occur too late in process
Too many price adjustments at checkout
Too many problems require management sign offs
Marketing offer not clear
Policies not clear
Policies
Not enough staffing during peak times
Incomplete training on common complaints
Unfamiliarity with procedures
For vacation notification
Notification of absence
Workforce

Analysis Tool examples

Scatter Plot

- Is their a relationship between two measures or indicators?



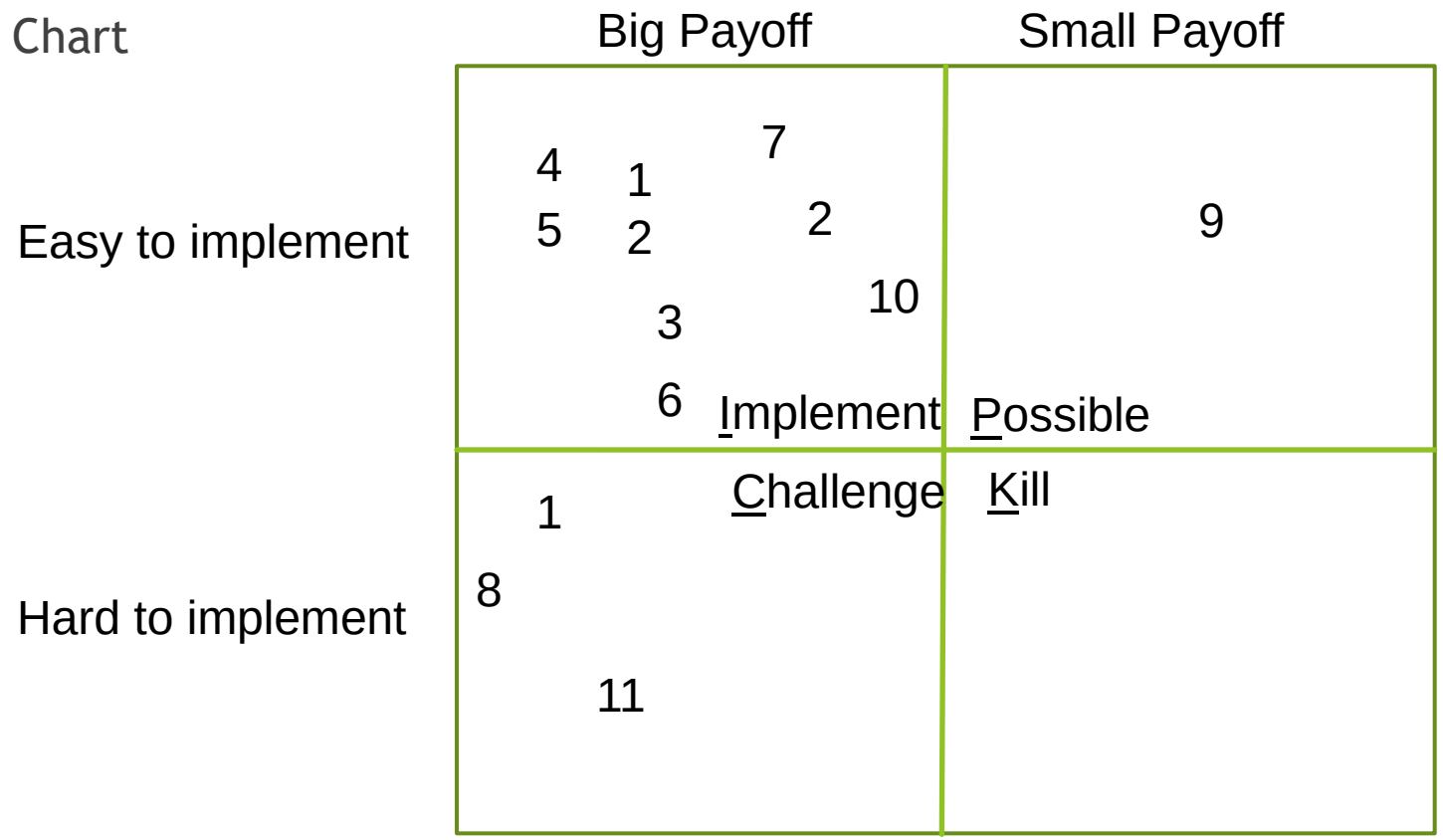
D-M-A-IMPROVE-C

D-M-A-IMPROVE-C

- Make process changes to eliminate defects, waste, costs that are linked to the customer needs identified in “define”
- Use creativity exercises
- Develop criteria for selecting solutions
- Piloting the chosen solution
- Planning for full-scale implementation

IMPROVE Tool example

- Pick Chart



D-M-A-I-CONTROL

D-M-A-I-CONTROL

- Ensure that any gains will last
- Create procedures & work aids
  - Help people to do their jobs differently from now on
- Document the new, improved procedures
- Train everyone!
- Set up procedures for tracking key “vital signs”
- Hand-off on-going management to process owner
- Complete the documentation process

D-M-A-I-CONTROL will….

- Prevent backsliding
  - Hard to change habits
- React quickly to future problems
  - Quick response
- Share the learning with others in your organisation

Cost of Quality

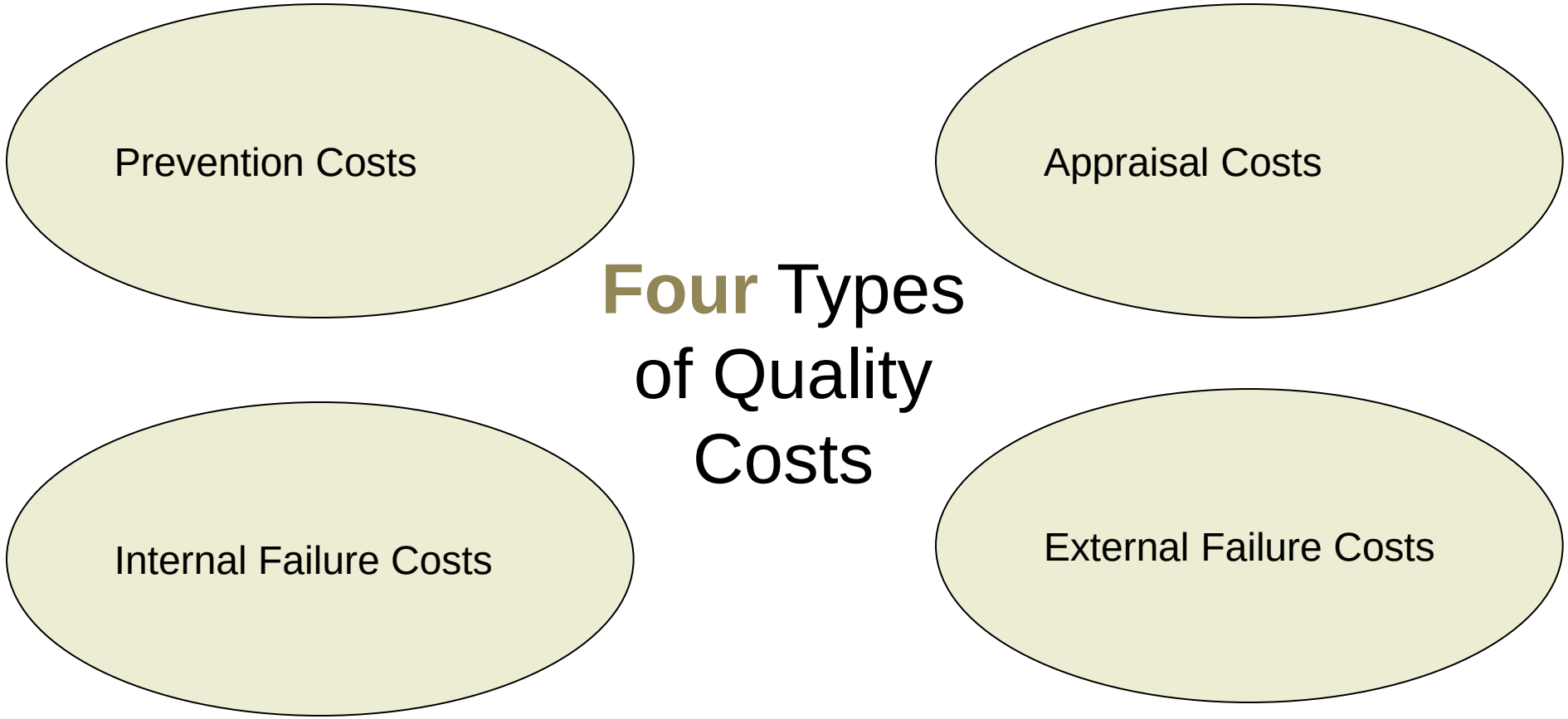
What are Quality Costs?

A Quality Cost is considered to be any cost that a company incurs in order to ensure that the quality of the product or service is perfect.

Quality cost are the portion of the operating costs brought about by providing a product or service that does not conform to performance standards.

Quality costs are also the costs associated with the prevention of poor quality

Cost of Quality



Also have Intangible Costs

Prevention Costs

Costs that occur when a company is performing activities designed to prevent poor quality in products or services

Appraisal Costs

Costs associated with measuring, evaluating, or auditing products or services to make sure that they conform to specifications or requirements

Failure Costs

Failure costs occur when the completed product or service does not conform to customer requirements

Internal Failure Costs

Those costs associated with product non-conformities or service failures found before the product is shipped or the service is provided to the customer.

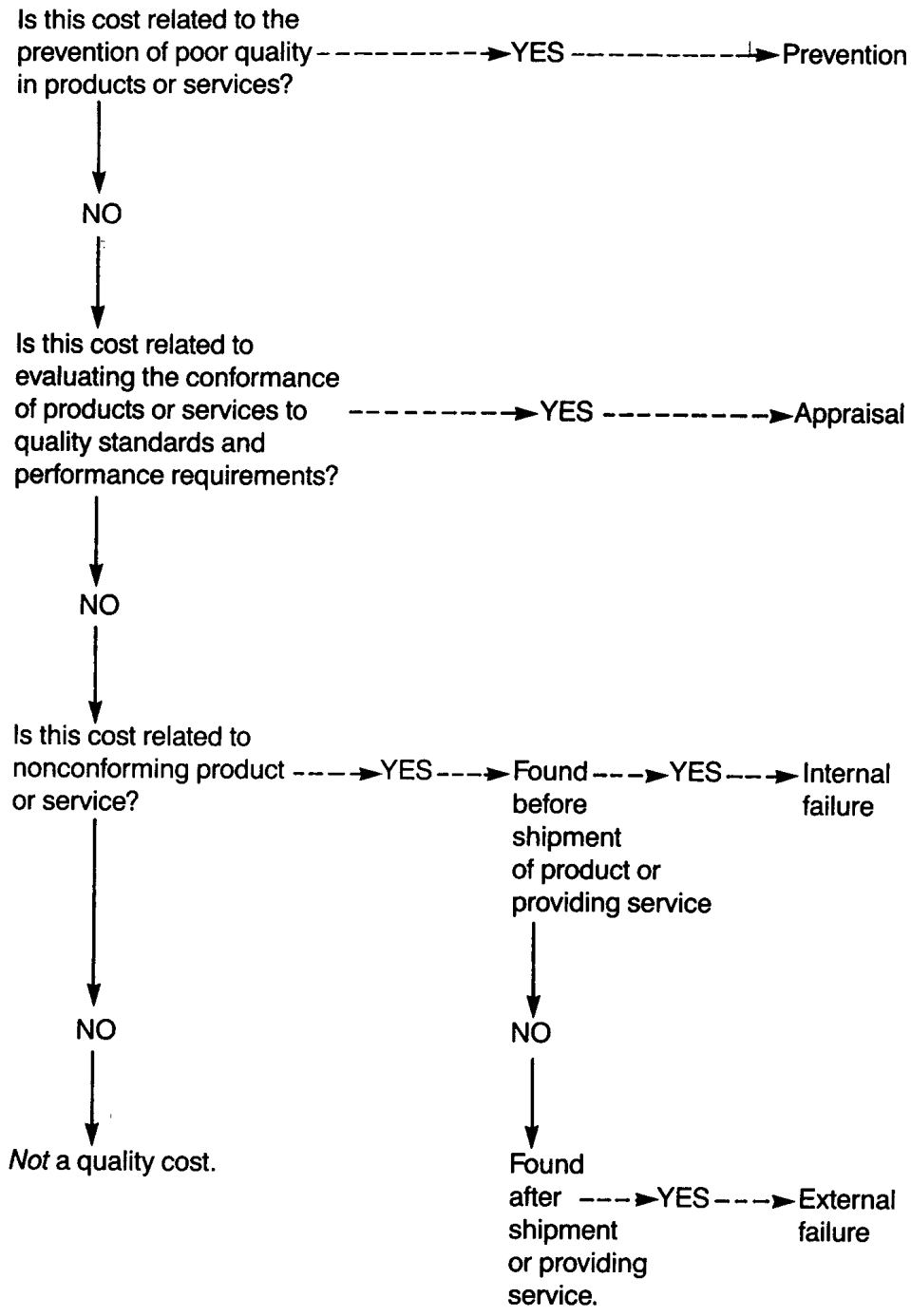
External Failure Costs

Those cost that occur when a non-conforming product or service reaches the customer

Intangible Costs

Costs that are hidden and associated with providing a non conforming product or service to a customer. They involve the companys image

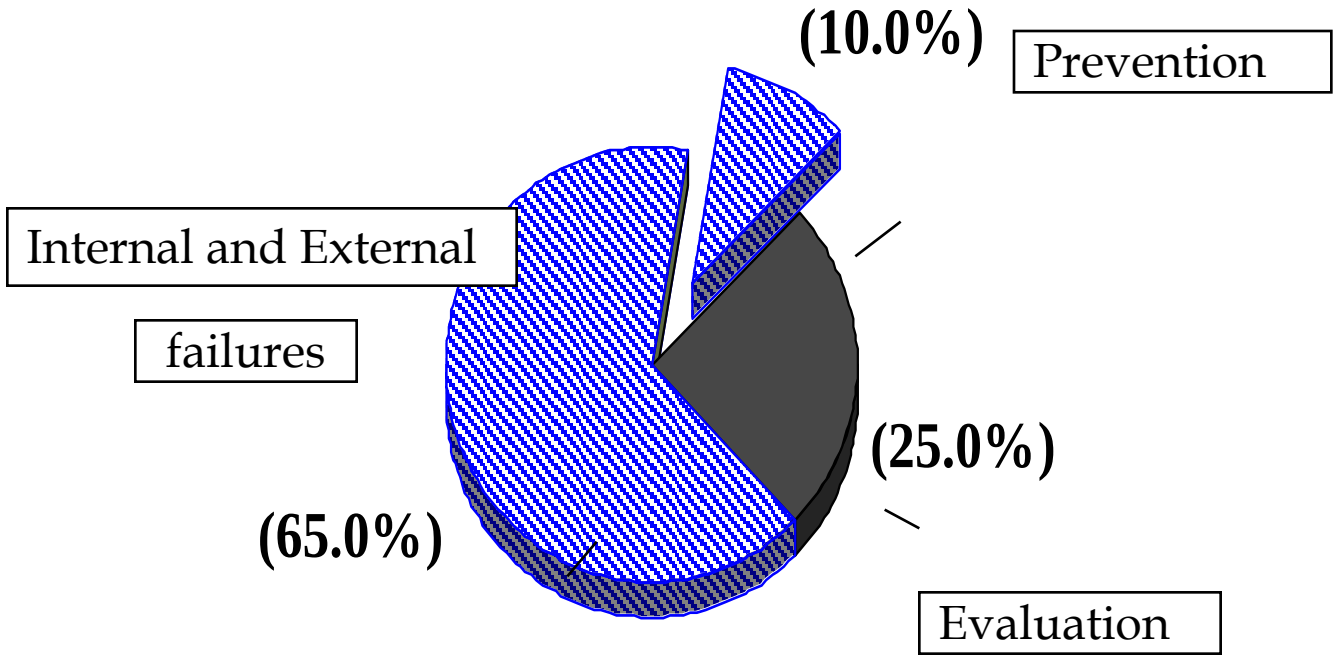
Classifying Quality Costs



Quality Cost - Examples

- Prevention
  - ☑ Preventing Defects from Happening
    - Quality Planning
    - Training
    - Verification of Design
    - Plant and Equipment Maintenance
    - Qualifying Suppliers
- Appraisal
  - ☑ Evaluating Materials and Performance
    - Incoming materials Inspection
    - In-process Inspection
    - Final End-item Inspection
    - Maintenance of test Equipment
    - Training
    - Calibration
- Internal Failures
  - ☑ Defects that are Discovered In-House
    - Scrap (waste)
    - Re-work
    - Time spent analyzing failures
    - Tests and re-tests
    - Operations downtime
    - *Internal Customer* Complaints
- External Failures
  - ☑ Defects Discovered by the Customer
    - Liability
    - Customer Complaints
    - Warranty Costs and Field Re-Work
    - Damaged Image

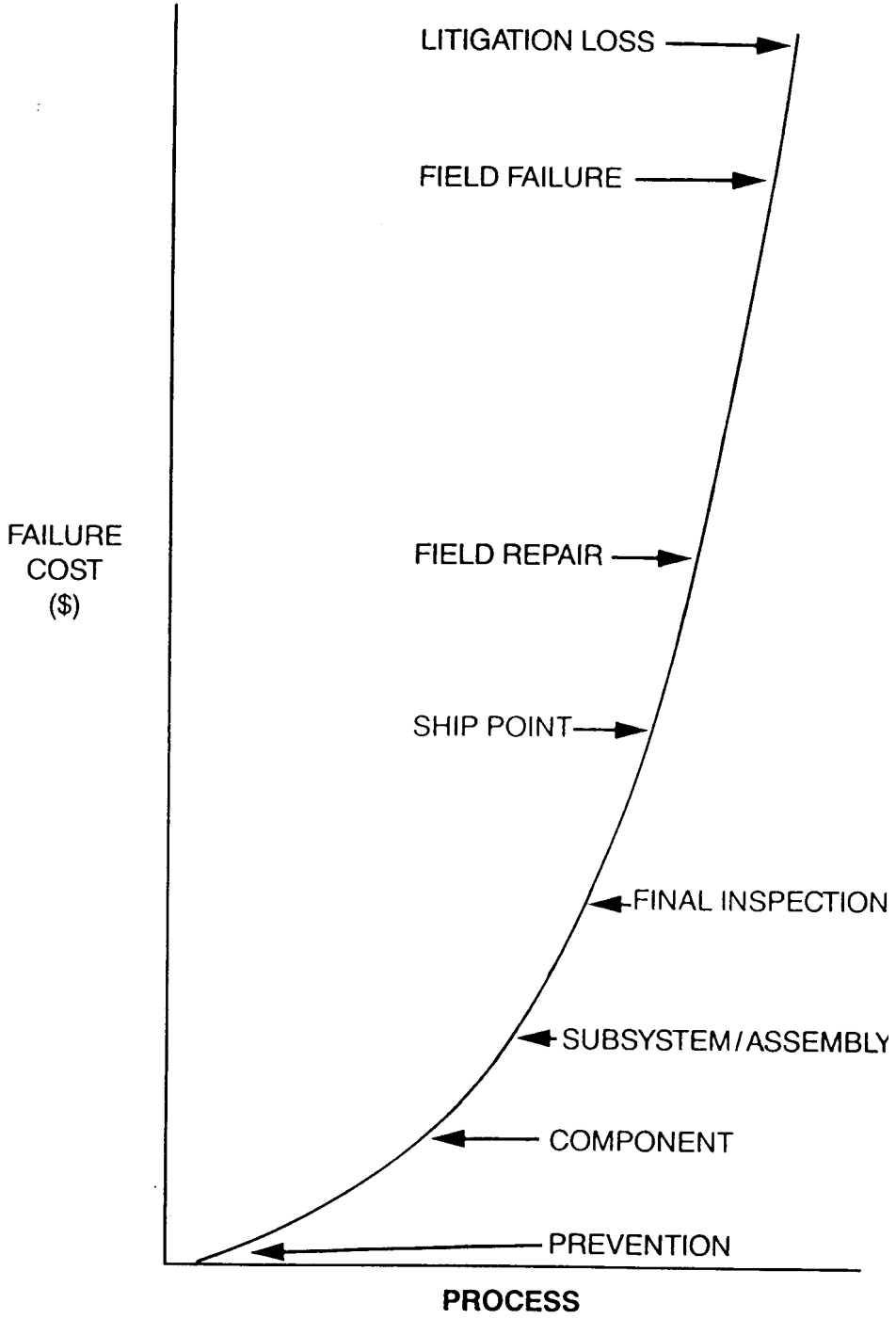
Distribution of Quality Costs



Reduce Quality Costs by Increasing Prevention Efforts

1-10-100 Rule

- Theory Says:
  - Prevention – €1
  - Inspect and Prevent – €10
  - Given to Customer – €100



COST OF QUALITY AND ORGANIZATIONAL OBJECTIVES

- The costs of doing a quality job, conducting quality improvements, and achieving goals must be carefully managed so that the long-term effect of quality on the organization is a desirable one.
- These costs must be a true measure of the quality effort, and they are best determined from an analysis of the costs of quality.
- Such an analysis provides a method of assessing the effectiveness of the management of quality and a means of determining problem areas, opportunities, savings, and action priorities.
- Cost of quality is also an important communication tool to raise awareness of the importance of quality.
- Many organizations will have true quality-related costs as high as 15-20% of sales revenue, some going as high as 40% of total operations. A general rule of thumb is that costs of poor quality in a thriving company will be about 10-15% of operations.
- Effective quality improvement programs can reduce this substantially, thus making a direct contribution to profits.
- The quality cost system, once established, should become dynamic and have a positive impact on the achievement of the organization's mission, goals, and objectives.

Evaluation of Qualify Costs as a Cost Basis

- **Why?**
  - Allow comparison across different periods
- **Typical Bases**
  - Internal failure as a % of Direct Labour costs
  - Internal failure as a % of total production costs
  - External failure as an average percent of net sales
  - Procurement appraisal costs as a percent of total purchased material costs
  - Operations appraisal costs as a percent of total production costs
  - Total quality costs as a percent of production costs

Quality Cost Basis Example- as a % of Direct Labour costs

	January		February	
Cost Category	**Product A**	**Product B**	**Product A**	**Product B**
Prevention	€2,000	€4,000	€2,000	€4,000
Appraisal	€10,000	€20,000	€13,000	€21,000
Internal Failure	€19,000	€106,000	€16,000	€107,000
External Failure	€54,000	€146,000	€52,000	€156,000
Total	€85,000	€276,000	€83,000	€288,000
Standard Direct Labour Costs	€35,000	€90,000	€28,000	€86,000

Quality Cost Basis Solution

Cost category	January		February	
	Product A	Product B	Product A	Product B
Prevention	0.057	0.044	0.071	0.047
Appraisal	0.286	0.222	0.464	0.244
Internal failure	0.543	1.178	0.571	1.244
External failure	1.543	1.622	1.857	1.814
Total	2.429	3.067	2.964	3.349

Quality Cost Basis - Ratios

- **Labour index**
  - quality cost / labour hours
- **Cost index**
  - quality cost / manufacturing cost
- **Sales index**
  - quality cost / sales
- **Production index**
  - quality cost / units produced

Quality Index Example

	2023	2022	2021	2020
Quality Costs				
Prevention	€ 27,000	41,500	74,600	112,300
Appraisal	155,000	122,500	113,400	107,000
Internal failure	386,400	469,200	347,800	219,100
External failure	242,000	196,000	103,500	106,000
Total	€ 810,400	829,200	639,300	544,400
Accounting measures				
Sales	€ 4,360,000	4,450,000	5,050,000	5,190,000
Mfg costs	1,760,000	1,810,000	1,880,000	1,890,000

Quality Index
Quality Costs as % of Sales

For Year 2023:
Total quality costs * 100 / Sales
€810,400 * 100 / 4,360,000 = 18.58

Year	Sales	Mfg Cost
2022	18.58	46.04
2021	18.63	45.18
2020	12.66	34.00
2019	10.49	28.80

Quality as % of Sales

The following table provides a general idea of the impact of varying Sigma performance levels (Defective Parts per million-DPPM).

SIGMA	DPPM	COST OF POOR PROCESS
1	691462.5	
2	308537.5	30–40% of sales
3	66807.2	20–30% of sales
4	6209.7	15–20% of sales
5	232.6	10–15% of sales
6	3.4	less than 10% of sales

Quality And Productivity

- Productivity = output / input
- Fewer defects increase output
- Quality improvement reduces inputs

Measuring Yield & Productivity

$$Y = (I)(\%G) + (I)(1-\%G)(\%R)$$

where

Y = yield

I = number units started in production

% G = percentage good units

% R = percentage of defective units reworked

Product Yield Example

- Start 100 motors per day
- 80% are good
- 50% of poor quality units can be reworked
- How many motors will be available for shipment at the end of the day?

$$Y = (I)(\%G) + (I)(1-\%G)(\%R)$$

$$Y = 100\ (0.80) + 100\ (1- 0.80)\ (0.50)$$

$$= 90 \text{ motors}$$

Product Cost

$$= \frac{(\text{direct mfg cost})(\text{input}) + (\text{unit rework cost})(\text{reworked units})}{\text{yield}}$$

$$= \frac{(K_d)(I) + (K_r)(R)}{Y}$$

where

K_d = direct manufacturing cost

I = input

K_r = rework cost per unit

R = reworked units

Y = yield

Product Cost Example

- Direct mfg cost = €30, Rework cost = €12
- 100 motors started, 20% defective
- 50% of defective motors can be reworked
- What is the cost to produce each motor?

$$\text{Product cost} = \frac{(K_d)(I) + (K_r)(R)}{Y}$$

$$= \frac{(€30)(100) + (€12)(10)}{\textbf{90 motors}} = €34.67 \text{ per motor}$$

Reduce the number of defects from 10 to 5

$$\text{Product cost} = \frac{(K_d)(I) + (K_r)(R)}{Y}$$

$$= \frac{(€30)(100) + (€12)(5)}{\textbf{95 motors}} = €32.21 \text{ per motor}$$

Multistage Product Yield

$Y = (I)\ (\%g_1)(\%g_2)\ldots(\%g_n)$

where

I = input batch size

$\%g_i$ = percent good at stage I

Multistage Process Yield

Motors produced in four-stage process

Start with 100 motors

Stage	% Good quality
1	0.93
2	0.95
3	0.97
4	0.92

$Y = (I)\ (\%g_1)(\%g_2)...(\%g_n) = (100)(0.93)(0.95)(0.97)(0.92)$

$Y = 78.8$ motors

Input Required For Output Of 100 Good Motors

$$I = \frac{Y}{(\%g_{1})(\%g_{2})(\%g_{3})(\%g_{4})}$$

$$I = \frac{100}{(0.93)(0.95)(0.97)(0.92)}$$

$$= 126.9 \quad \textit{Motors}$$

Advantages of a Quality Cost System

- Provides a manageable entity and a single view of quality
- Aligns quality and company goals
- Provides a problem prioritization system and a means of measuring change
- Provides a way to distribute controllable quality costs for maximum profits
- Improves the effective use of resources
- Provides emphasis for doing job right every time
- Helps to establish new product processes

Limitations of a Quality Cost System

- Quality cost measurement does not solve quality problems
- Quality cost report do not suggest specific actions
- Quality costs are susceptible to short-term mismanagement
- It is often difficult to match effort and accomplishment
- Important costs may be omitted from quality cost reports
- Inappropriate costs may be included in quality cost report
- Many quality costs are susceptible to measurement errors

Six Sigma & Quality Costs

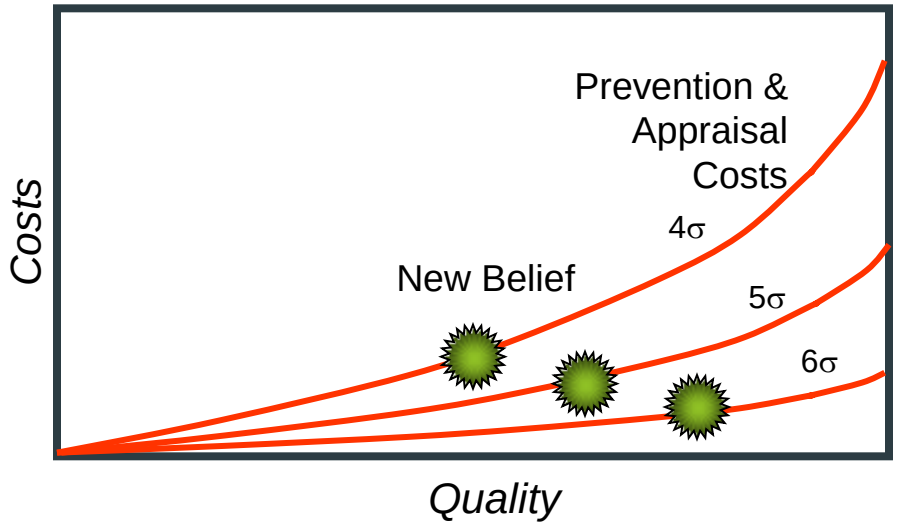
σ is a measure of how much variation exists in a process

Old Belief

High Quality = High Cost

New Belief

High Quality = Low Cost



“Quality is Free”

- For the average company, the cost of quality is about 25% of total sales
- The cost of prevention is a fraction of the cost of fixing mistakes after they are made
- Investments in prevention can drastically reduce the total cost of quality

End of Lecture